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ABSTRACT

This curriculum guide contains a course in hydraulics to train entry-level workers for automotive mechanics and other fields that utilize hydraulics. The module contains 14 instructional units that cover the following topics: (1) introduction to hydraulics; (2) fundamentals of hydraulics; (3) reservoirs; (4) lines, fittings, and couplers; (5) seals; (6) fluids and filters; (7) pumps; (8) valves; (9) cylinders; (10) motors; (11) accessories; (12) hydraulic circuits, diagrams, and symbols; (13) general maintenance; and (14) diagnosis and testing. Each instructional unit follows a standard format that includes some or all of these eight basic components: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to tests. All unit components focus on measurable and observable learning outcomes and are designed for use in more than one lesson or class period. (KC)

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Hydraulics

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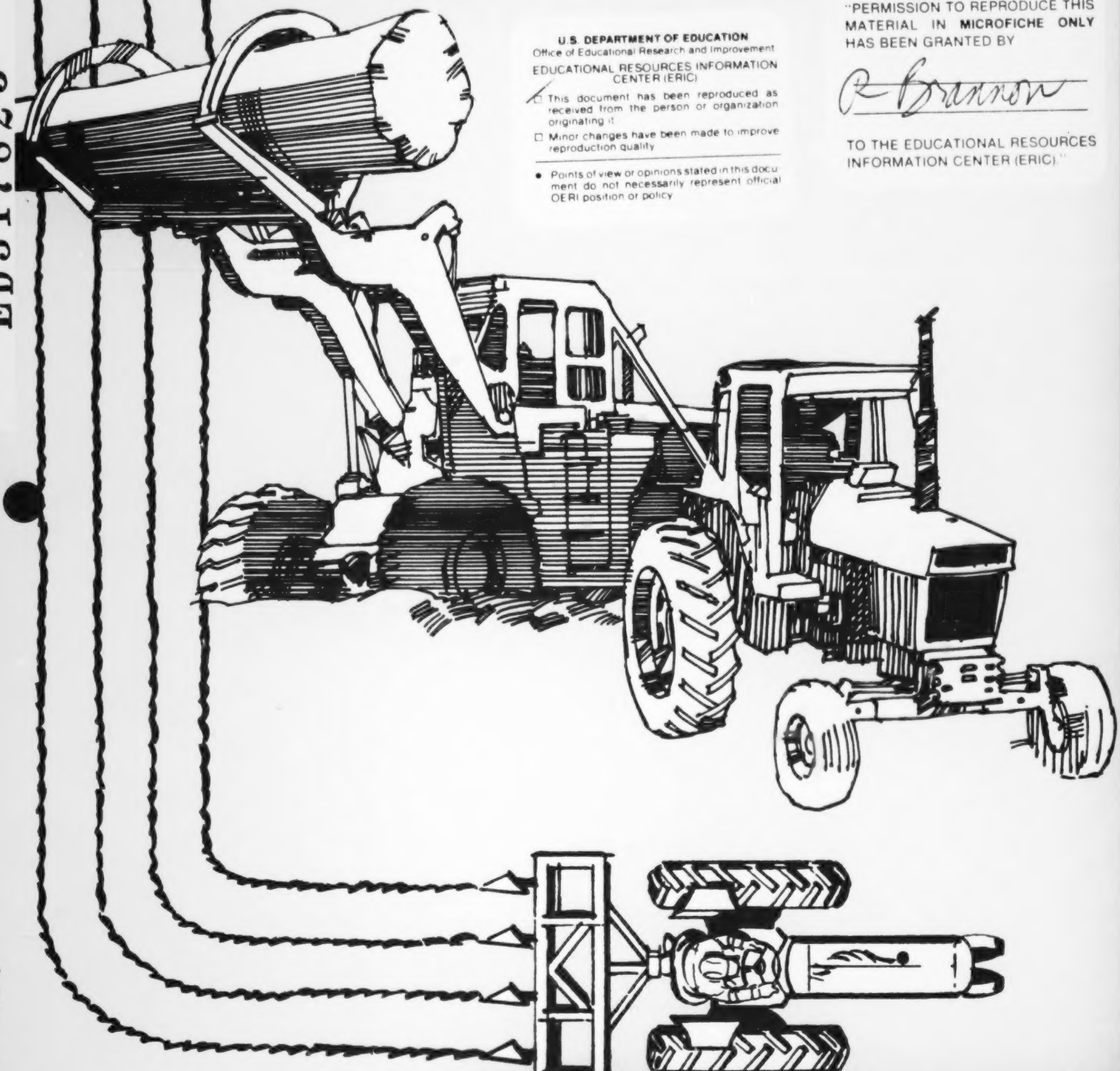

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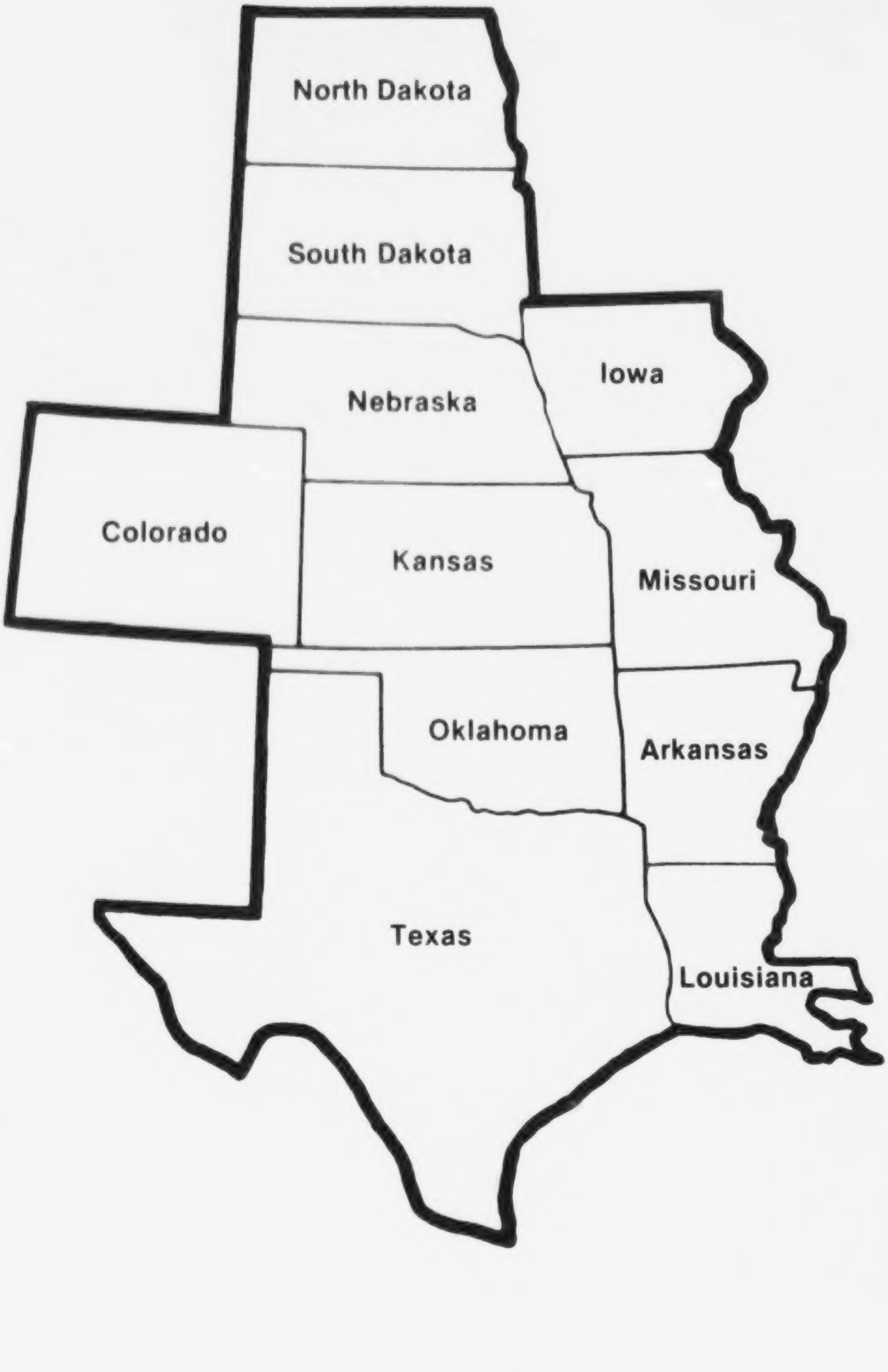
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HYDRAULICS

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HYDRAULICS

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FOREWORD

Competency-based instructional texts are like most other books in one respect — every now and then they must be revised. Revision is built into the MAVCC development process. After a book is printed and disseminated, a file is maintained of instructor suggestions for changes or additions to the text. In fact, letters and phone calls from instructors who use MAVCC materials are the finest source of guidelines for revision.

Along with items from the suggestion file, MAVCC gathers an *ad hoc* committee to review a given text and make recommendations for revision. The procedure assures that MAVCC books reflect state-of-the-art materials, equipment, and processes.

Instructor suggestions for changes and additions to *Hydraulics* included areas where terminology needed clarification or change. Other suggestions indicated need for minor additions in some of the job sheets. In short, instructors who use *Hydraulics* generally told MAVCC that it was an excellent text just the way it was.

That's why this current revision of *Hydraulics* seems to be very much like the original. According to both instructor and committee input, the book simply didn't need major revisions. That's a credit to Robert Decker, the original author. Yet, there have been significant revisions in objectives related to open and closed-center systems. At numerous points, terminology has been corrected to clarify ambiguous points in the text, and some of the job sheets have been expanded to enhance their instructional value. But even when you count the new illustrations that have been added, you will still feel you're using the original text, and that's a credit to Klane Kirby for his splendid work with the revision.

Hydraulics has been on MAVCC's best-seller list since its first publication in 1980. That's a sure sign the book has played a positive role in many vo-tech classrooms. We think the revised edition of *Hydraulics* will keep up the good work. After all, that's what MAVCC's all about.

Les Abel, Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

PREFACE

I can only imagine what the next revision of *Hydraulics* will entail. But whatever it does demand, I know it will all be easier if MAVCC continues to receive input from instructors who use *Hydraulics*.

When you find an error, or a point where an addition is needed to clarify an objective, we'd like to hear from you. It's nice if you have time to write. In fact, many instructors who do write us send copies of the materials with their additions or changes noted at specific points where they should go. We enjoy hearing from instructors who will take that much time, but we enjoy hearing from anyone with a good suggestion and hope that if you don't have time to write, you'll call us toll-free at 1-800-654-3988.

To the best of my knowledge this is the finest introductory hydraulic text that I know about. In fact, it's the only one in a good, solid competency-based format. It has truly earned its place on MAVCC's best-seller list.

Greg Pierce
Executive Director
Mid-America Vocational
Curriculum Consortium

ACKNOWLEDGEMENTS

Special appreciation is extended to the members of the original Resource Committee who dedicated much time to the identification of tasks and objectives for the text, and for their careful review of the materials after they were written. The Resource Committee includes:

Roger Miller, Salina, Kansas
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C.F. Kirkpatrick, Levelland, Texas
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For his valuable assistance in helping with many of the difficult technical elements in the book, a special thank you goes to **Harlan Gjorass,** Training Instructor, Kearns Machinery Company/Caterpillar Tractor Company, Sioux Falls, South Dakota.

Another vote of thanks goes to Leslie Mathis from the Graphics Department of Oklahoma Vo-Tech for her fine work with the phototypesetting of this revised edition of *Hydraulics*.

For editing, thanks to Regina Decker, Kathy Dolan, and Dan Fulkerson.

For a fine job of printing, a final thank you to the printing staff of the Oklahoma State Department of Vocational-Technical Education.

USE OF THIS PUBLICATION

Instructional Units

Hydraulics includes fourteen units. Each instructional unit includes some or all of the basic components of a unit of instruction; performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to the tests. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

A. The amount of material that can be covered in each class period
B. The skills which must be demonstrated

   1. Supplies needed
   2. Equipment needed
   3. Amount of practice needed
   4. Amount of class time needed for demonstrations

C. Supplementary materials such as pamphlets or filmstrips that must be ordered
D. Resource people who must be contacted

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

10

Suggested Activities for the Instructor

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

Transparency Masters

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledge which is a necessary prerequisite to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

Job Sheets

Job sheets are an important segment of each unit. The instructor should be able to demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

Test and Evaluation

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

Test Answers

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

HYDRAULICS

INSTRUCTIONAL/TASK ANALYSIS

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT I: INTRODUCTION TO HYDRAULICS

1. Definition of hydraulics
2. Systems utilizing hydraulics
3. Advantages and disadvantages of hydraulics
4. Hazards to safety when working with hydraulic systems
5. Safety practices for working on hydraulic systems

UNIT II: FUNDAMENTALS OF HYDRAULICS

1. Terms and definitions
2. Functions of hydraulic fluids
3. Calculation of pressure
4. Pascal's law
5. Operating principles of a hydraulic press
6. Bernoulli's theorem
7. Components of a basic hydraulic circuit
8. Power transfer in a hydraulic system
9. Components of a hydraulic jack
10. Operation of a hydraulic jack
11. Draw a block diagram of a simple hydraulic system
12. Disassemble, clean and reassemble a hydraulic jack

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
UNIT III: RESERVOIRS	
	1. Definition of reservoir
	2. Types of reservoirs
	3. Reasons for using a pressurized reservoir
	4. Functions of a reservoir
	5. Parts of a vented reservoir
	6. Parts of a pressurized reservoir
	7. Symbols for reservoirs
8. Clean and inspect a vented reservoir	
UNIT IV: LINES, FITTINGS, AND COUPLERS	
	1. Terms and definitions
	2. Characteristics of steel pipe
	3. Types, construction, and size of steel tubing
	4. Characteristics of hydraulic hose
	5. Types of fittings used with tubing
	6. Types of hose-ends used in hydraulic systems
	7. Types of fittings used in hydraulic systems
	8. Factors to consider when routing tubing in hydraulic systems
	9. Conditions to avoid when routing hydraulic hose
10. Replace a reusable hose end	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT V: SEALS

1. Terms and definitions
2. Types of leakage paths in hydraulic systems
3. Types of sealing devices used in hydraulic systems
4. Types of seals and their applications
5. Types of seal construction
6. Factors to consider concerning seal material
7. Install an O-ring
8. Install a seal
9. Install a packing

UNIT VI: FLUIDS AND FILTERS

1. Terms and definitions
2. Effects of contaminants in a hydraulic system
3. Practices for assuring hydraulic system cleanliness
4. Functions of a filter in a hydraulic system
5. Surface and depth filters
6. Locations and types of filters in a hydraulic system
7. Types of filter circuits
8. Factors in specifying a filter
9. Symbol for a filter
10. Functions of fluid in hydraulic systems
11. Effect of temperature on the viscosity of hydraulic fluids
12. Common additives in hydraulic systems
13. Safety rules to remember when working with hydraulic fluid

JOB TRAINING: What the
Worker Should Be Able to Do
(Psychomotor)

RELATED INFORMATION: What
the Worker Should Know
(Cognitive)

UNIT VII: PUMPS

1. Terms and definitions
2. Positive and nonpositive displacement pumps
3. Kinds of positive displacement pumps
4. Calculation of pump displacement
5. Calculation of pump flow rate
6. Calculation of pump input and output power
7. Calculation of pump volumetric efficiency
8. Operation of gear pump
9. Operation of vane pumps
10. Axial and radial piston pumps
11. Operation of a radial piston pump
12. Types of axial piston pumps
13. Construction and operation of axial piston pumps
14. Operation of a variable displacement axial piston pump
15. Parts of a servo-controlled variable displacement pump
16. Components and functions of pressure compensated axial piston pumps
17. Causes of cavitation
18. Causes of pump failure
19. Symbols for pumps

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

20. Disassemble, inspect, and reassemble a gear pump
21. Disassemble, inspect, and reassemble a pressure compensated variable displacement pump

UNIT VIII: VALVES

1. Terms and definitions
2. Categories of valves
3. Types of pressure control valves
4. Types of pressure relief valves
5. Operation of a pressure reducing valve
6. Types of flow control valves
7. Operation of a needle valve as a flow control device
8. Operation of a high pressure compensated flow control valve
9. Operation of a priority flow divider
10. Operation of a proportional flow divider
11. Types of directional control valves
12. Operation of a check valve and a spool direction control valve
13. Flow paths in a directional control valve
14. Open and closed center systems
15. Types of actuators

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	16. Symbols for hydraulic valves
17. Disassemble, inspect, and reassemble a pressure control valve	
18. Disassemble, inspect, and reassemble a flow control valve	
19. Disassemble, inspect, and reassemble a directional control valve	

UNIT IX: CYLINDERS

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	1. Terms and definitions
	2. Operations of a hydraulic cylinder
	3. Operations of single and double-acting cylinders
	4. Types of double-acting cylinders
	5. Parts of a single-acting cylinder
	6. Parts of a double-acting cylinder
	7. Sources of common failures of hydraulic cylinders
	8. Force output of a cylinder
	9. Speed of a hydraulic cylinder
	10. Power output of a hydraulic cylinder
	11. Flow rate required to move a cylinder a given distance in a given time
	12. Symbol for a cylinder
13. Disassemble, inspect, and reassemble a hydraulic cylinder	
14. Test a cylinder for internal and external leakage	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT X: MOTORS

1. Terms and definitions
2. Kinds of hydraulic motors
3. Formula for calculating hydraulic motor load torque
4. Formula for calculating displacement of motor
5. Formula for calculating speed of a motor
6. Formula for calculating inlet pressure
7. Formula for calculating motor input and output
8. Formula for calculating overall motor efficiency
9. Operation of a gear motor
10. Operation of an unbalanced motor vane
11. Types of piston motors
12. Operation of an in-line axial piston motor
13. Disassemble, inspect, and reassemble a gear motor

UNIT XI: ACCESSORIES

1. Terms associated with accessories
2. Functions of an accumulator
3. Types of accumulators
4. Types of gas-loaded accumulators
5. Safety precautions for working with accumulators
6. Reasons for using a cooler
7. Types of coolers
8. Components of an air-cooled cooler and their functions
9. Common failures of coolers

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	10. Reasons for using a heater
	11. Types of heaters
	12. Failures of heaters
13. Inspect, clean, and test an air-cooled cooler	
14. Inspect, clean, and test a heater	

UNIT XII: HYDRAULIC CIRCUITS, DIAGRAMS, AND SYMBOLS

	1. Terms and definitions
	2. Components of a basic hydraulic circuit
	3. Types of hydraulic circuits
	4. Advantages and disadvantages of open-center and closed-center systems
	5. Fluid flow in an open-center circuit
	6. Fluid flow in multiple actuator open-center systems
	7. Valves in neutral and shifted positions in fluid flow
	8. Symbols used in a hydraulic schematic
	9. Symbols for directional control valves
	10. Schematic of open and closed-center systems
11. Draw an open-center hydraulic circuit	
12. Show the oil flow in a circuit	

UNIT XIII: GENERAL MAINTENANCE

	1. Reasons for preventive maintenance
	2. Factors that can damage hydraulic systems
	3. Key maintenance problems

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	4. Steps for keeping a hydraulic system clean
	5. Steps for general maintenance of a hydraulic system
6. Perform general maintenance procedures on a hydraulic system	
7. Change hydraulic fluid and filter	

UNIT XIV: DIAGNOSIS AND TESTING

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	1. Terms associated with diagnosis and testing
	2. Steps in troubleshooting
	3. Types of hydraulic system testers
	4. Problems and remedies for an inoperative system
	5. Problems and remedies for an erratic system
	6. Problems and remedies for a slow system
	7. Problems and remedies for a fast system
	8. Problems and remedies for a overheated system
	9. Problems and remedies for the foaming of fluid
	10. Problems and remedies for excessive noise
	11. Problems and remedies for a leaking pump
	12. Problems and remedies for a load drop
	13. Problems causing valves to stick or work hard

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	14. Problems causing control valves to leak
	15. Problems causing a cylinder to leak
	16. Problems in lowering and raising with a control valve
	17. Problems and remedies for power steering malfunctions
	18. Problems and remedies for brake malfunctions
19. Test a hydraulic pump	
20. Locate a problem in a hydraulic system	
21. Test a relief valve	
22. Test a control valve	
23. Test an actuator	

HYDRAULICS

Tools, Equipment, and Materials List

- Air-cooled cooler
- Caps to cover fluid ports
- Cylinder
- Cylinder text fixture
- Cylinder using wiper seal
- Directional control valve
- Double-acting cylinder
- Emery cloth
- Fitting assembly with O-ring seal
- Flow control valve
- Gear motor
- Gear pump
- Hand tool set
- Hose with reusable hose ends
- Hydraulic filter
- Hydraulic fluid
- Hydraulic jack
- Hydraulic power supply
- Hydraulic system-defective
- Hydraulic system-open center
- Hydraulic system tester
- Hydraulic system with actuator
- Knife
- Lint free rope
- Lint free towels
- Motor shaft speed measure
- O-ring
- O-ring remover tool
- Packings
- Pressure compensated pump
- Pressure control pump
- Replacement hose
- Replacement piston seal
- Replacement rod seal
- Replacement wiper seal
- Safety glasses
- Screwdriver
- Seal installation tool
- Shipping plugs
- Solvent
- Tape measure
- Vented reservoir
- Vise
- Wiper seal
- Wrenches

ALPHABETICAL LIST OF REFERENCES USED IN DEVELOPING THIS TEXT

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INTRODUCTION TO HYDRAULICS
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to discuss advantages and disadvantages of hydraulics, name hazards to safety when working with hydraulic systems, and safety practices when working on hydraulic systems. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Define hydraulics.
2. Select systems which utilize hydraulics.
3. Discuss advantages and disadvantages of hydraulics.
4. Name six hazards to safety when working with hydraulic systems.
5. List five safety practices when working on hydraulic systems.

INTRODUCTION TO HYDRAULICS
UNIT I

SUGGESTED ACTIVITIES

A. Provide students with objective sheet.

B. Provide students with information sheet.

C. Discuss unit and specific objectives.

D. Discuss information sheet.

E. Show examples of different types of systems which utilize hydraulics.

F. Demonstrate hazards that can occur when working with hydraulic systems.

G. Demonstrate safety procedures which should be practiced when working with hydraulics.

H. Contact a local or area Ford tractor dealer and request that the dealer show students the Ford tractors sales video entitled *Tractor Hydraulics, Closed Center Remote Valves;* the production discusses Ford's closed center systems, but the production also deals with open center systems and students should benefit from the effective materials the program contains.

I. Give test.

CONTENTS OF THIS UNIT

A. Objective sheet

B. Information sheet

C. Test

D. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Fundamentals of Service, Hydraulics.* Moline, IL: Deere and Company, 1976.

B. Pippinger, John J. and Tyler G. Hicks. *Industrial Hydraulics.* Dallas, TX: Gregg Division/McGraw-Hill Book Company, 1979.

INTRODUCTION TO HYDRAULICS
UNIT I

INFORMATION SHEET

I. **Hydraulics** — The study of fluids in motion or at rest

II. **Systems which utilize hydraulics**

(NOTE: There are many systems which utilize hydraulic power. The following are some of the applications on different types of machinery.)

- A. Hitch controls
  1. Three point hitch controls are used for up and down depth control
  2. Remote couplers provide outlets for cylinder operation on devices such as log splitters
- B. Backhoe

  (NOTE: A backhoe is a commonly used piece of construction equipment.)
- C. Power steering

  (NOTE: Power steering systems are commonly used on automobiles, trucks, construction equipment, and agricultural equipment.)
- D. Machine tools
  1. Numerically controlled milling machine
  2. Industrial robot
- E. Brakes

  (NOTE: Hydraulic brakes can be found on automobiles, trucks, construction equipment, and agricultural tractors.)
- F. Auxiliary controls and actuators

III. **Advantages and disadvantages of hydraulics**

- A. Advantages
  1. Flexibility — Allows a flexible transfer of large forces
  2. Multiplication of force — Small forces can be used to control large forces

INFORMATION SHEET

3. Simplicity
    a. Has fewer moving parts and points of wear than a mechanical system
    b. Is able to lubricate itself
4. Compactness — Hydraulic motors are more compact than electrical motors of equal horsepower
5. Economy
    a. Low installation cost
    b. Low operating cost
6. Safety — Hydraulic systems have fewer moving parts and present fewer potential hazards than mechanical systems with gears and chains

B. Disadvantages

1. Safety — High pressure is potentially dangerous
2. Cleanliness — System must be kept very clean to prevent excessive wear of the components
3. Leaks — With almost any system under pressure, leaks are inevitable

IV. Safety hazards when working with hydraulic systems

A. Components subjected to excessive pressure may explode

B. Accidental release of trapped oil in hydraulic circuits supporting booms or attachments may cause these components to malfunction or fall suddenly

C. Hot oil from leaks, disconnected lines, or reservoir drains can cause severe burns

D. Pin-hole leaks in high pressure circuits can release potentially dangerous fluids

E. Many hydraulic fluids are extremely flammable

F. Some hydraulic fluids can irritate or burn when they come in contact with the skin or eyes

INFORMATION SHEET

V. **Safety practices when working on hydraulic systems**

A. Support booms and attachments before working on a hydraulic system

B. Operate all control levers to insure hydraulic pressure has been relieved

C. Loosen lines and components in a circuit slowly to relieve trapped pressure

D. Stop equipment and repair leaks immediately

E. Wear safety glasses and a safety helmet as required when working with any system under pressure

INTRODUCTION TO HYDRAULICS
UNIT I

NAME ____________________

TEST

1. Define hydraulics. ____

____

2. Select systems which utilize hydraulics by placing an "X" in the appropriate blanks.

_____a. Brakes

_____b. Power steering

_____c. Hitch control

_____d. Mechanical differential

_____e. Machine tools

3. Discuss four advantages and two disadvantages of hydraulics.

a. Advantages

1) ____

2) ____

3) ____

4) ____

b. Disadvantages

1) ____

2) ____

4. Name six hazards to safety when working with hydraulic systems.

a. ____

b. ____

c. ____

TEST

d. ______________________________

e. ______________________________

f. ______________________________

5. List five safety practices when working on hydraulic systems.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

INTRODUCTION TO HYDRAULICS
UNIT I

ANSWERS TO TEST

1. The study of fluids in motion or at rest

2. a, b, c, e

3. Discussion should include four of the following advantages and the two disadvantages
   a. Advantages
      1) Flexibility — Allows a flexible transfer of large forces
      2) Multiplication of force — Small forces can be used to control large forces
      3) Simplicity
         a) Has fewer moving parts and points of wear than a mechanical system
         b) Is able to lubricate itself
      4) Compactness — Hydraulic motors are more compact than electrical motors of equal horsepower
      5) Economy
         a) Low installation cost
         b) Low operating cost
      6) Safety — Hydraulic systems have fewer moving parts and present fewer potential hazards than mechanical systems with gears and chains
   b. Disadvantages
      1) Safety — High pressure is potentially dangerous
      2) Cleanliness — System must be kept very clean to prevent excessive wear of the components
      3) Leaks — With almost any system under pressure, leaks are inevitable

4. a. Components subjected to excessive pressure may explode
   b. Accidental release of trapped oil in hydraulic circuits supporting booms or attachments may cause these components to malfunction or fall suddenly
   c. Hot oil from leaks, disconnected lines, or reservoir drains can cause severe burns
   d. Pin-hole leaks in high pressure circuits can release potentially dangerous fluids
   e. Many hydraulic fluids are extremely flammable
   f. Some hydraulic fluids can irritate or burn when they come in contact with the skin or eyes

5. a. Support booms and attachments before working on a hydraulic system
   b. Operate all control levers to insure hydraulic pressure has been relieved
   c. Loosen lines and components in a circuit slowly to relieve trapped pressure
   d. Stop equipment and repair leaks immediately
   e. Wear safety glasses and a safety helmet as required when working with any system under pressure

FUNDAMENTALS OF HYDRAULICS
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to discuss the four functions of hydraulic fluids and select true statements concerning the power transfer in a hydraulic system. The student should also be able to identify the components of a basic hydraulic circuit and a hydraulic jack and disassemble, clean, inspect, and reassemble a hydraulic jack. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student will be able to:

1. Match terms associated with fundamentals of hydraulics with their correct definitions.
2. Discuss briefly four functions of hydraulic fluids.
3. Calculate pressure when given force and area.
4. State Pascal's law.
5. Explain the operating principles of a hydraulic press.
6. Discuss Bernoulli's theorem.
7. Identify the components of a basic hydraulic circuit.
8. Select true statements concerning the power transfer in a hydraulic system.
9. Identify the components of a hydraulic jack.
10. Distinguish between the lifting and lowering of a hydraulic jack.
11. Draw a block diagram of a simple hydraulic system.
12. Demonstrate the ability to disassemble, clean, and reassemble a hydraulic jack. (Job Sheet #1)

FUNDAMENTALS OF HYDRAULICS
UNIT II

SUGGESTED ACTIVITIES

A. Provide students with objective sheet.

B. Provide students with information, assignment, and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information and assignment sheets.

F. Demonstrate and discuss the procedures outlined in the assignment and job sheets.

G. Demonstrate how hydraulic pressure is calculated.

H. Show examples of hydraulic jacks and assist students in identifying components.

I. Let students practice operating hydraulic jack in order to understand operation.

J. Give test.

CONTENTS OF THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1 — Calculation of Hydraulic Pressure
2. TM 2 — Basic Hydraulic Press
3. TM 3 — Bernoulli's Theorem
4. TM 4 — Block Diagram of Hydraulic System
5. TM 5 — Operation of a Hydraulic Jack

D. Assignment Sheet #1 — Draw a Block Diagram of a Simple Hydraulic System

E. Job Sheet #1 — Disassemble, Clean, and Reassemble a Hydraulic Jack

F. Test

G. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Fundamentals of Service, Hydraulics.* Moline, IL: Deere and Company, 1976.

B. *Industrial Hydraulics Manual.* Troy, MI: Sperry Rand Corporation, 1970.

FUNDAMENTALS OF HYDRAULICS
UNIT II

INFORMATION SHEET

I. **Terms and definitions**

A. Hydraulics — The study of fluids in motion or at rest

B. Fluid — A substance which has no shape of its own

C. Pressure — The force exerted over a surface divided by its area

D. Liquid — A fluid which is relatively incompressible

(NOTE: A gas is a fluid that can be compressed.)

E. Reservoir — A container for keeping a supply of working fluid in a hydraulic system

F. Pump — A device which creates the flow of hydraulic fluid

(NOTE: A pump converts mechanical energy into hydraulic energy.)

G. Line — A tube, pipe, or hose for conducting a fluid

H. Valve — A device which controls either pressure of fluid, direction of fluid flow, or rate of flow

I. Actuator — A device which converts hydraulic energy into mechanical energy

Example: Hydraulic cylinders
Hydraulic motors

J. Cylinder — An actuator which converts hydraulic energy into linear or rotary mechanical energy

(NOTE: Rotary cylinders usually rotate less than one full revolution.)

K. Motor — An actuator which converts hydraulic energy into rotary mechanical energy

L. Cooler — An optional component that has a main function of cooling hydraulic fluid

II. **Functions of hydraulic fluids**

A. Power transmission — Provides a medium for transferring force from one location to another

INFORMATION SHEET

B. Lubrication — Lessens friction on internal surfaces of hydraulic system components in order to reduce wear

C. Sealing — Reduces flow through leakage paths

D. Cooling — Provides a medium for removing heat generated in the system

III. **Calculation of pressure** (Transparency 1)

A. Determine force

B. Determine area of surface to which force is applied

C. Divide force by area of surface to which force is applied

(NOTE: Pressure is normally measured in units of pounds per square inch (PSI). Therefore, the force should be expressed in units of pounds, and area should be expressed in square inches.)

Example: If the force is four pounds, and the area equals 2 square inches, then the pressure will be 2 PSI.

IV. **Pascal's law** — Pressure on a confined fluid is transmitted undiminished in every direction to the surface of the containing vessel

V. **Operating principles of a hydraulic press** (Transparency 2)

(NOTE: The operation of a hydraulic press is an example of the application of Pascal's law.)

A. A hydraulic press consists of two pistons supported by a quantity of hydraulic fluid

B. A force on one piston creates a pressure in the hydraulic fluid equal to the force divided by the piston area

C. Pascal's law states the pressure will be equal at all points within the fluid including the fluid at the second piston

D. The force applied by the second piston is equal to the pressure times the area of the second cylinder

(NOTE: This is an example of force multiplication in a hydraulic system.)

VI. **Bernoulli's theorem** (Transparency 3)

(NOTE: The following discussion does not take into account friction loss in the pipe.)

A. Fluid flowing in a pipe will have some pressure and flow rate

INFORMATION SHEET

B. If the cross-sectional area of the pipe decreases, then the pressure will decrease

(NOTE: The flow rate will increase.)

C. If the cross-sectional area increases to its original size, then the pressure will return to its original value

(NOTE: The flow rate will also return to its original value.)

VII. **Components of a basic hydraulic circuit** (Transparency 4)

A. Reservoir

B. Pump

C. Lines

D. Valves (optional)

   1. Bypass valves

   2. Relief valves (cartridge valves)

   3. Control valves

   4. Check valves

E. Actuator

   1. Motor

   2. Cylinder

F. Cooler (optional)

VIII. **Power transfer in a hydraulic system**

A. Power is supplied into pump from

   1. Electric motor

   2. Gasoline or diesel engine

   3. Manual

B. Mechanical power is converted to hydraulic power by the pump

C. Hydraulic power is transmitted by lines

INFORMATION SHEET

- D. Hydraulic power is regulated by valves
- E. Hydraulic power is converted to mechanical power by actuators
    - 1. Motor
    - 2. Cylinder

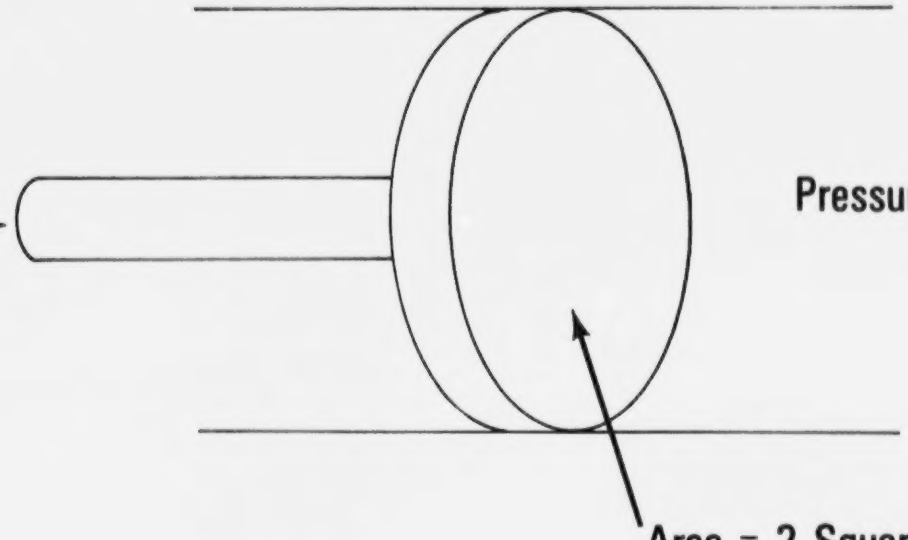
IX. **Components of a hydraulic jack** (Transparency 5)

- A. Reservoir
- B. Pump
- C. Actuator (cylinder)
- D. Check valve 1
- E. Check valve 2
- F. Release valve

X. **Operation of a hydraulic jack** (Transparency 5)

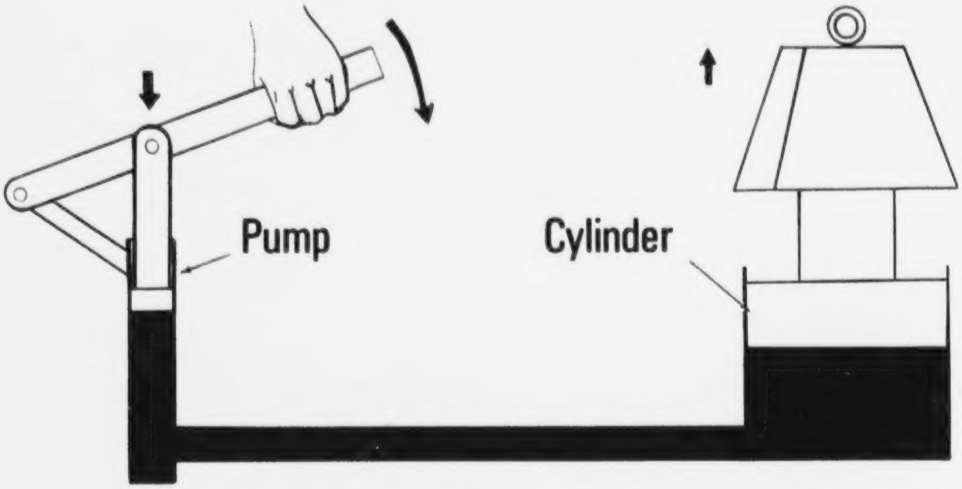
- A. Lifting
    - 1. Fluid is pulled from reservoir through check valve 1 on upward stroke of hand pump
    - 2. Check valve 2 is closed by a spring
    - 3. Fluid is forced past check valve 2 to cylinder to raise object on downward stroke of hand pump
    - 4. Check valve 1 is closed by a spring
- B. Lowering
    - 1. Release valve is opened to return fluid to reservoir
    - 2. Pumping with the release valve open causes fluid to circulate from reservoir to pump them back to reservoir

Calculation of Hydraulic Pressure

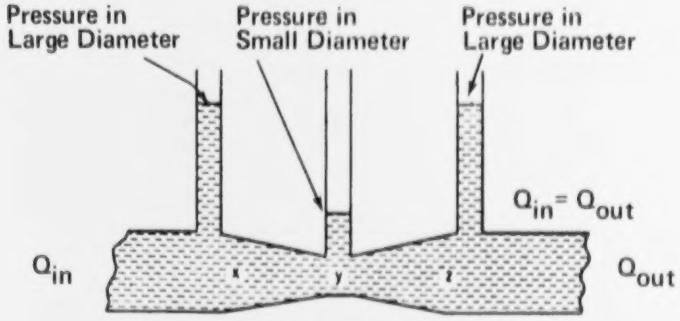

4 lbs.
Area = 2 Square Inches

$$\text{Pressure} = \frac{4 \text{ lbs.}}{2 \text{sq. in.}} = 2\text{PSI.}$$

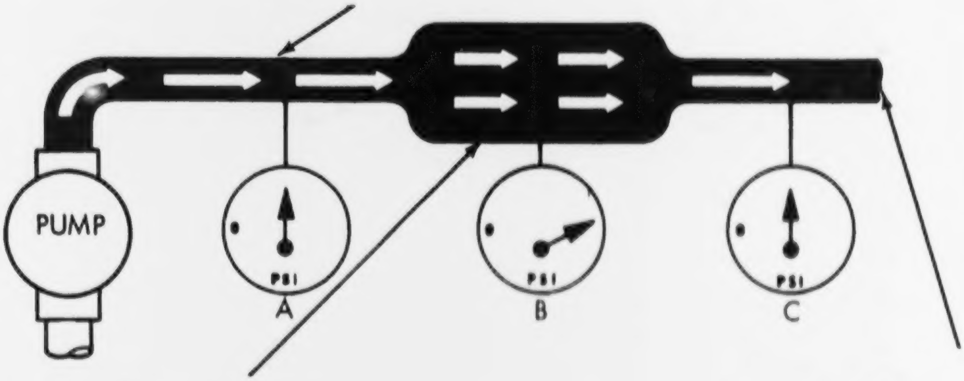
Basic Hydraulic Press


Pump
Cylinder

Bernoulli's Theorem


Pressure in Large Diameter
Pressure in Small Diameter
Pressure in Large Diameter
Q in = Q out
Q in
x
y
z
Q out

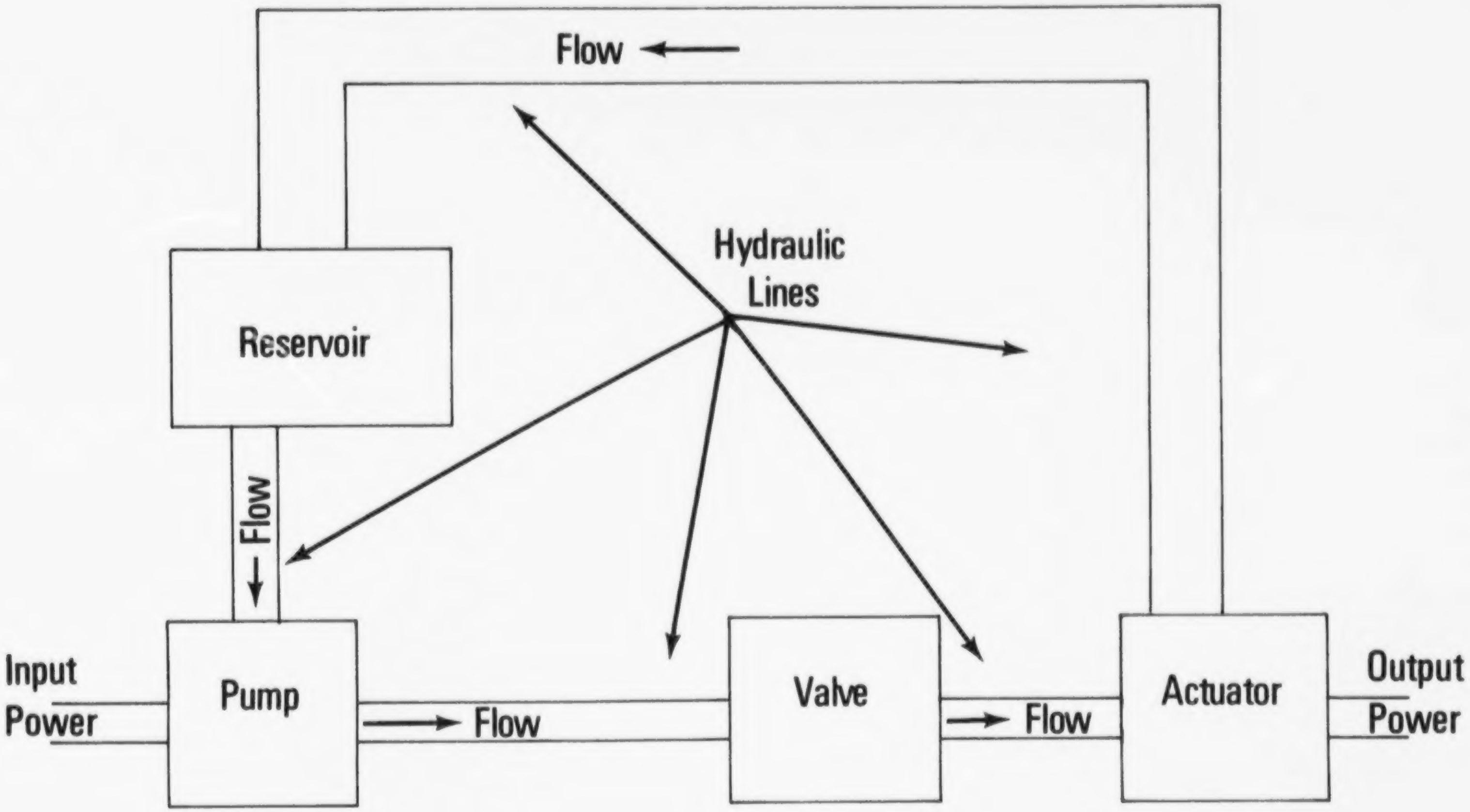
1. In the Small Section Pipe, Velocity is Maximum. More Energy is in the Form of Motion, So Pressure is Lower.


PUMP
PSI
A
PSI
B
PSI
C

2. Velocity Decreases in the Larger Pipe. The Kinetic Energy Loss is Made Up by an Increase in Pressure.

3. Ignoring Friction Losses, the Pressure Again Becomes the Same as at "A" When the Flow Velocity Becomes the Same as at "A"

Block Diagram of Hydraulic System



Flow

Hydraulic Lines

Reservoir

Flow

Input Power

Pump

Flow

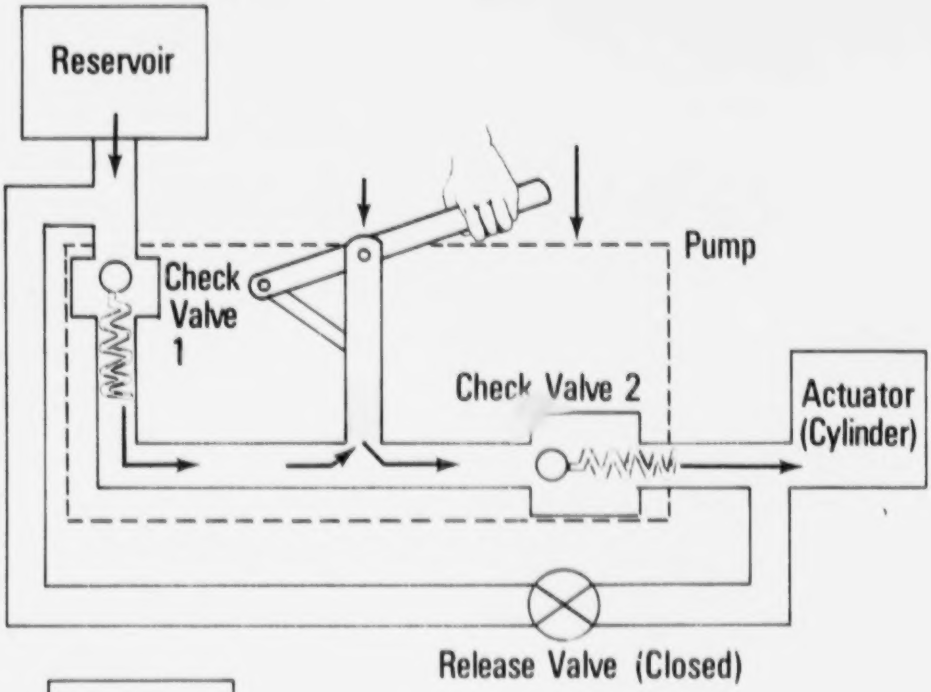
Valve

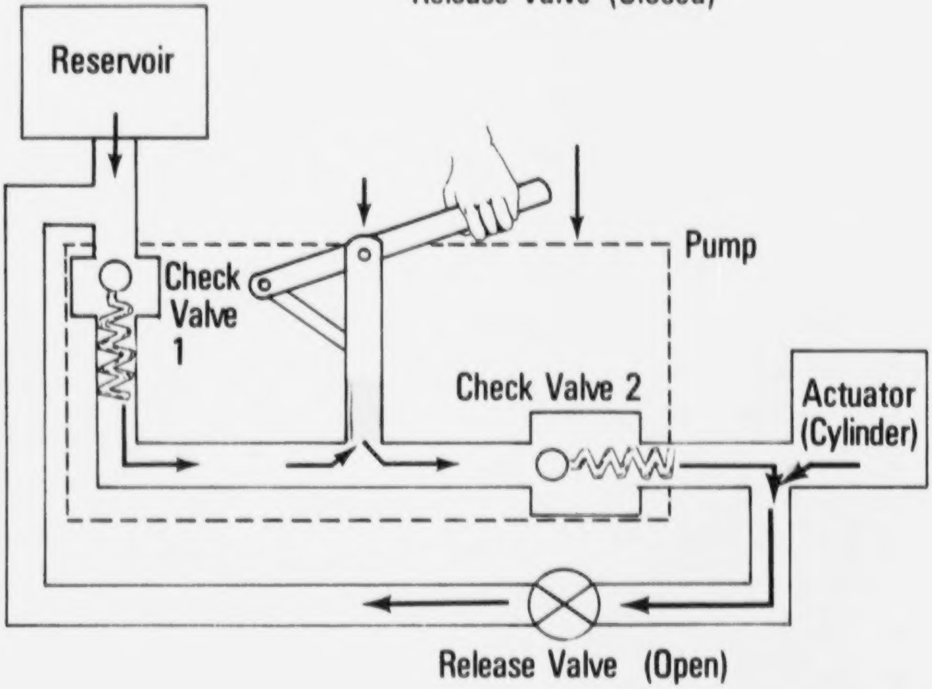
Flow

Actuator

Output Power

Operation of a Hydraulic Jack


Reservoir
Pump
Check Valve 1
Check Valve 2
Actuator (Cylinder)
Release Valve (Closed)


Reservoir
Pump
Check Valve 1
Check Valve 2
Actuator (Cylinder)
Release Valve (Open)

FUNDAMENTALS OF HYDRAULICS
UNIT II

ASSIGNMENT SHEET #1 — DRAW A BLOCK DIAGRAM OF A SIMPLE HYDRAULIC SYSTEM

Directions: Draw a block diagram of a simple hydraulic system showing a reservoir, pump, valves, lines, and actuator. Designate flow direction by drawing arrows in the lines.

FUNDAMENTALS OF HYDRAULICS
UNIT II

JOB SHEET #1 — DISASSEMBLE, CLEAN, AND REASSEMBLE A HYDRAULIC JACK

A. Tools and materials

1. Hydraulic jack
2. Hand tools
3. Lint free shop towels
4. Solvent
5. Hydraulic fluid for jack
6. Vise
7. Safety glasses

B. Routine #1 — Disassemble jack

1. Use the solvent to clean any dirt or grease from the external surfaces
2. Place the jack on a clean surface for disassembly
3. Remove the drain plug and drain oil from the jack
4. Remove the retaining nut which holds the ram (cylinder) in place
5. Remove the ram
6. Remove pumping piston
7. Remove the check valve balls and spring
8. Remove the release valve

☐ Have your instructor check your work

C. Routine #2 — Clean and inspect the jack

1. Use the solvent to clean all of the removed parts and housing internal surfaces
2. Inspect all surfaces for damage
3. Inspect seals for nicks and cuts

JOB SHEET #1

4. Replace seals

☐ Have your instructor check your work

D. Routine #3 — Reassemble the jack

1. Install the release valve
2. Install the check valve balls and spring
3. Make sure balls are properly seated and operate properly
4. Install pumping piston with seal
5. Install the ram with seal
6. Install the retaining ring
7. Fill with fluid

   (NOTE: It may be necessary to bleed air from the jack.)

8. Test the operation of the jack

☐ Have your instructor check your work

9. Clean up area and return tools and materials to proper storage

FUNDAMENTALS OF HYDRAULICS
UNIT II

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. The study of fluids in motion or at rest

_____b. A substance which has no shape of its own

_____c. The force exerted over a surface divided by its area

_____d. A fluid which is relatively incompressible

_____e. A container for keeping a supply of working fluid in a hydraulic system

_____f. A device which creates the flow of hydraulic fluid

_____g. A tube, pipe, or hose for conducting a fluid

_____h. A device which controls either pressure of fluid, direction of fluid flow, or rate of flow

_____i. A device which converts hydraulic energy into mechanical energy

_____j. An actuator which converts hydraulic energy into linear or rotary mechanical energy

_____k. An actuator which converts hydraulic energy into rotary mechanical energy

_____l. An optional component that has the main function of cooling hydraulic fluid

1. Line
2. Fluid
3. Pump
4. Motor
5. Hydraulics
6. Liquid
7. Reservoir
8. Cylinder
9. Pressure
10. Actuator
11. Valve
12. Cooler

2. Discuss briefly four functions of hydraulic fluids.

a. ____

b. ____

c. ____

d. ____

TEST

3. Calculate pressure in the following problems when given area and force.

   a. Force = 100 lbs., Area = 10 square inches

   b. Force = 10 lbs., Area = 1 square inch

   c. Force = 5 lbs., Area = 1/2 square inch

4. State Pascal's law. ____________________

   ____

5. Explain the operating principles of a hydraulic press.

   a. ____________________

      ____

   b. ____________________

      ____

   c. ____________________

      ____

   d. ____________________

      ____

6. Discuss Bernoulli's theorem.

   a. ____________________

      ____

   b. ____________________

      ____

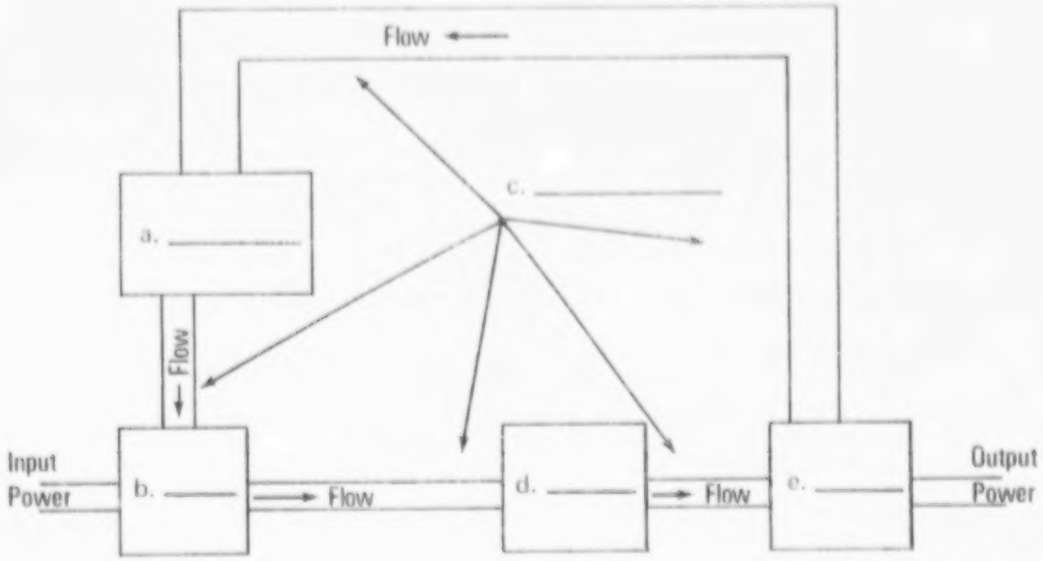
   c. ____________________

      ____

TEST

7. Identify the components of a basic hydraulic circuit.

Block Diagram of Hydraulic System



8. Select true statements concerning the power transfer in a hydraulic system by placing an "X" in the appropriate blanks.

______a. Power is supplied into the pump from the reservoir

______b. Mechanical power is converted to hydraulic power by the pump

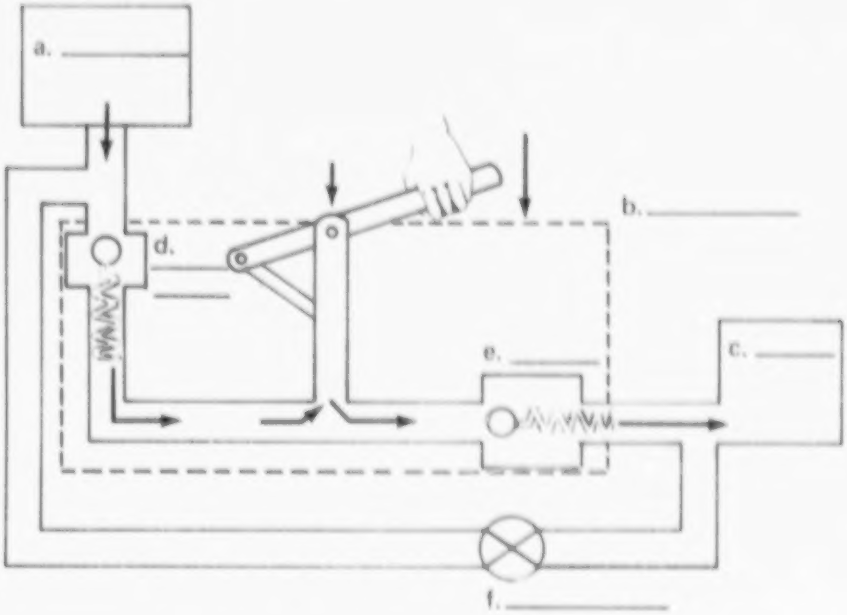
______c. Hydraulic power is transmitted by lines

______d. Hydraulic power is regulated by actuators

______e. Hydraulic power is converted to mechanical power by actuators

TEST

9. Identify the components of a hydraulic jack.



10. Distinguish between the lifting and lowering operation of a hydraulic jack by placing an "X" next to the description of the lowering operation.

_____a. 1) Release valve is opened to return fluid to reservoir

2) Pumping with the release valve open causes fluid to circulate from reservoir to pump then back to reservoir

_____b. 1) Fluid is pulled from reservoir through check valve 1 on upward stroke of hand pump

2) Check valve 2 is closed by a spring

3) Fluid is forced past check valve 2 to cylinder to raise object on downward stroke of hand pump

4) Check valve 1 is closed by a spring

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

11. Draw a block diagram of a simple hydraulic system.

12. Demonstrate the ability to disassemble, clean, inspect, and reassemble a hydraulic jack.

FUNDAMENTALS OF HYDRAULICS
UNIT II

ANSWERS TO TEST

1.

a.	5	e.	7	i.	10
b.	2	f.	3	j.	8
c.	9	g.	1	k.	4
d.	6	h.	11	l.	12

2. Discussion should include:
   a. Power transmission — Provides a medium for transferring force from one location to another
   b. Lubrication — Lessens friction on internal surfaces of hydraulic system components in order to reduce wear
   c. Sealing — Reduces flow through leakage paths
   d. Cooling — Provides a medium for removing heat generated in the system

3. a. 10 PSI
   b. 10 PSI
   c. 10 PSI

4. Pressure on a confined fluid is transmitted undiminished in every direction to the surface of the containing vessel

5. Explanation should include:
   a. A hydraulic press consists of two pistons supported by a quantity of hydraulic fluid
   b. A force on one piston creates a pressure in the hydraulic fluid equal to the force divided by the piston area
   c. Pascal's law states the pressure will be equal at all points within the fluid including the fluid at the second piston
   d. The force applied by the second piston is equal to the pressure times the area of the second cylinder

6. Discussion should include:
   a. Fluid flowing in a pipe will have some pressure and flow rate
   b. If the cross-sectional area of the pipe decreases, then the pressure will decrease
   c. If the cross-sectional area increases to its original size, then the pressure will return to its original value

7. a. Reservoir
   b. Pump
   c. Lines
   d. Valve
   e. Actuator

8. b, c, e

ANSWERS TO TEST

9. a. Reservoir
   b. Pump
   c. Actuator
   d. Check valve 1
   e. Check valve 2
   f. Release valve

10. a

11. Performance skills evaluated to the satisfaction of the instructor

12. Performance skills evaluated to the satisfaction of the instructor

RESERVOIRS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to select reasons for using a pressurized reservoir and functions of a reservoir. The student should also be able to draw symbols for reservoirs and clean and inspect a reservoir. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student will be able to:

1. Define reservoir.
2. Name two types of reservoirs.
3. Select reasons for using a pressurized reservoir.
4. Select functions of a reservoir.
5. Identify the parts of a properly designed, vented reservoir.
6. Identify the parts of a properly designed, pressurized reservoir.
7. Draw the symbol for a vented and pressurized reservoir.
8. Demonstrate the ability to clean and inspect a vented reservoir. (Job Sheet #1)

RESERVOIRS
UNIT III

SUGGESTED ACTIVITIES

A. Provide students with objective sheet.

B. Provide students with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheet.

G. Give test.

CONTENTS OF THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

   1. TM 1 — Parts of a Properly Designed, Vented Reservoir

   2. TM 2 — Parts of a Properly Designed, Pressurized Reservoir

D. Job Sheet #1 — Clean and Inspect a Vented Reservoir

E. Test

F. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Fluid Power I.* Cleveland, OH: Parker-Hannifin Corporation, 1979.

B. *Fundamentals of Service.* Moline, IL: Deere and Company, 1967.

C. *Industrial Hydraulics Manual.* Troy, MI: Sperry Rand Corporation, 1970.

RESERVOIRS
UNIT III

INFORMATION SHEET

I. **Reservoir** — Container for holding a supply of fluid

II. **Types of reservoirs**

  A. Vented to atmosphere

  B. Pressurized and sealed

III. **Reasons for using a pressurized reservoir**

  A. Contamination is reduced

  B. Condensation is reduced

  (NOTE: Some condensation is almost always present, especially in high humidity conditions.)

  C. Helps to force fluids to the pump

IV. **Functions of a reservoir**

  A. Provides fluid to replace system leakage

  B. Contains excess fluid resulting from system volume changes

  (NOTE: System volume changes occur when a cylinder is retracted or extended.)

  C. Helps to cool system

  D. Helps to separate dirt and air from fluid

V. **Parts of a properly designed, vented reservoir** (Transparency 1)

  A. Filler cap

  B. Fluid level gauge

  C. Baffle

    1. Separation baffle helps separate inlet fluid from outlet fluid and aids in air and dirt separation and cooling

    (NOTE: A separation baffle is used on almost all systems.)

INFORMATION SHEET

2. Pressure baffle prevents oil from being forced through a vent under pressures and is used only on systems that are vented

D. Reservoir outlet

(NOTE: The reservoir outlet goes to the pump.)

E. Return lines

F. Intake filter screen

(NOTE: The intake filter screen protects the pump.)

G. Drain plug

(NOTE: Some drain plugs are magnetic to help remove metal chips in fluid.)

H. Inspection plate

VI. **Parts of a properly designed, pressurized reservoir** (Transparency 2)

A. Filler cap

B. Fluid level gauge

C. Baffle

D. Reservoir outlet

E. Return lines

F. Intake filter screen

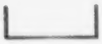
G. Drain plug

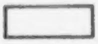
H. Inspection plate

I. Pressure regulator

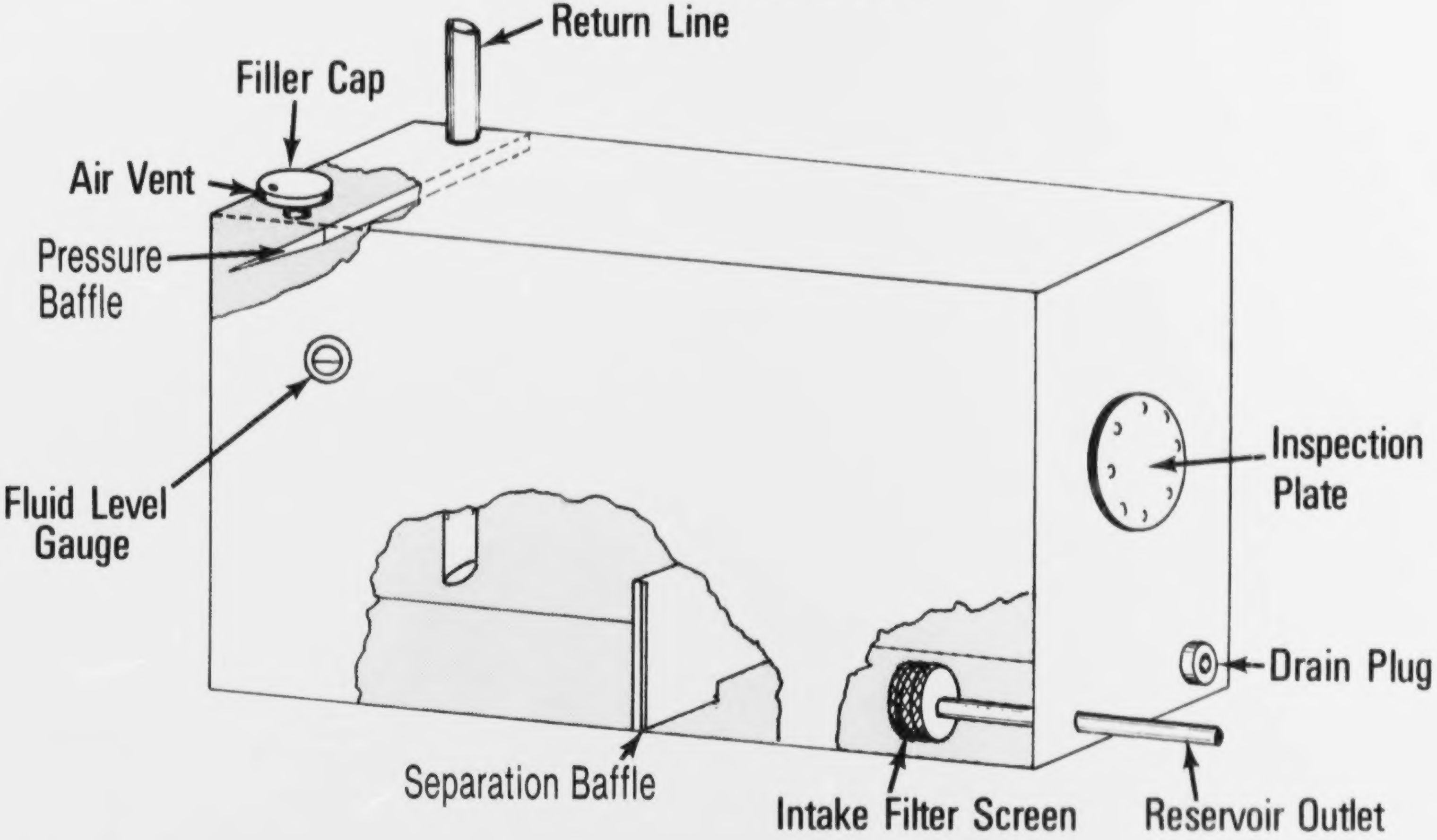
J. Air line

VII. **Symbols for reservoirs**

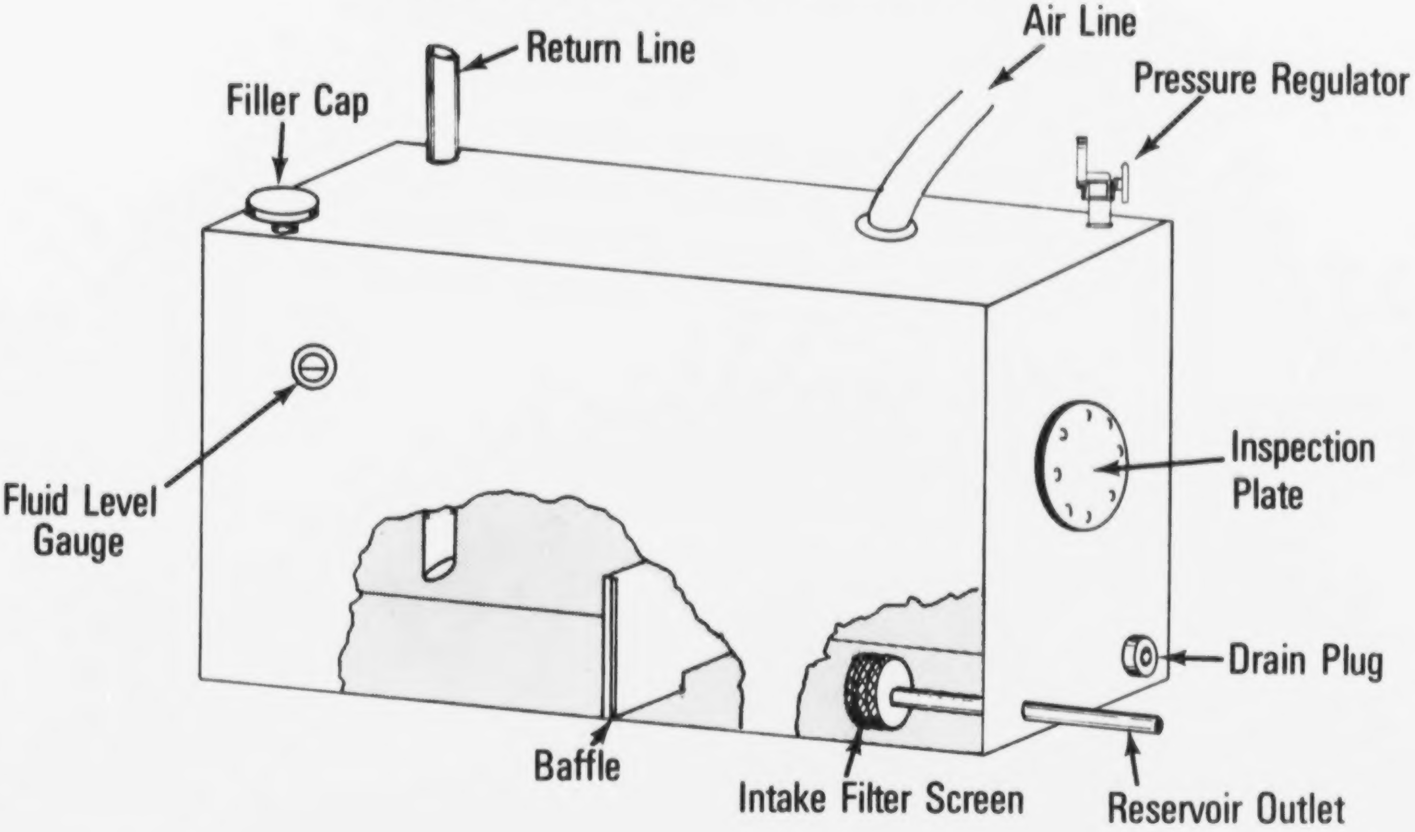
A. Vented 

B. Pressurized 

Parts of a Properly Designed, Vented Reservoir


Return Line
Filler Cap
Air Vent
Pressure Baffle
Fluid Level Gauge
Inspection Plate
Drain Plug
Separation Baffle
Intake Filter Screen
Reservoir Outlet

Parts of a Properly Designed, Pressurized Reservoir


Return Line
Air Line
Pressure Regulator
Filler Cap
Fluid Level Gauge
Inspection Plate
Drain Plug
Baffle
Intake Filter Screen
Reservoir Outlet

RESERVOIRS
UNIT III

JOB SHEET #1 — CLEAN AND INSPECT A VENTED RESERVOIR

A. Tools and materials

1. Wrenches (as required)
2. Screwdriver (as required)
3. Vented reservoir
4. Lint-free shop towel
5. Solvent
6. Safety glasses

B. Routine #1 — Clean reservoir

1. Drain fluid
2. Remove inspection plate
3. Remove sludge on bottom of reservoir with cloth wetted with solvent
4. Clean air vent

   (NOTE: Inspect relief valve on pressurized reservoir.)

5. Clean intake filter screen with solvent
6. Rinse inside of reservoir with solvent

C. Routine #2 — Inspect reservoir

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Examine reservoir for leaks, cracks, and broken welds		
2. Inspect inlet filter screen; replace if damaged		
3. Inspect filler cap to insure proper operation		
4. Check air vent to insure that it is not plugged		
5. Check operation of relief valve		

JOB SHEET #1

☐ Have your instructor check your work

6. Clean up area and return tools and materials to proper storage

RESERVOIRS
UNIT III

NAME ____________________

TEST

1. Define reservoir. ____

____

2. Name two types of reservoirs.

   a. ____

   b. ____

3. Select reasons for using a pressurized reservoir by placing an "X" in the appropriate blanks.

   ______a. Condensation is increased

   ______b. Contamination is reduced

   ______c. Helps to force the fluid to the baffle

   ______d. Condensation is reduced

   ______e. Helps to force fluids to the pump

4. Select functions of a reservoir by placing an "X" in the appropriate blanks.

   ______a. Helps to cool system

   ______b. Contains excess fluid resulting from system volume changes

   ______c. Connects main components of system

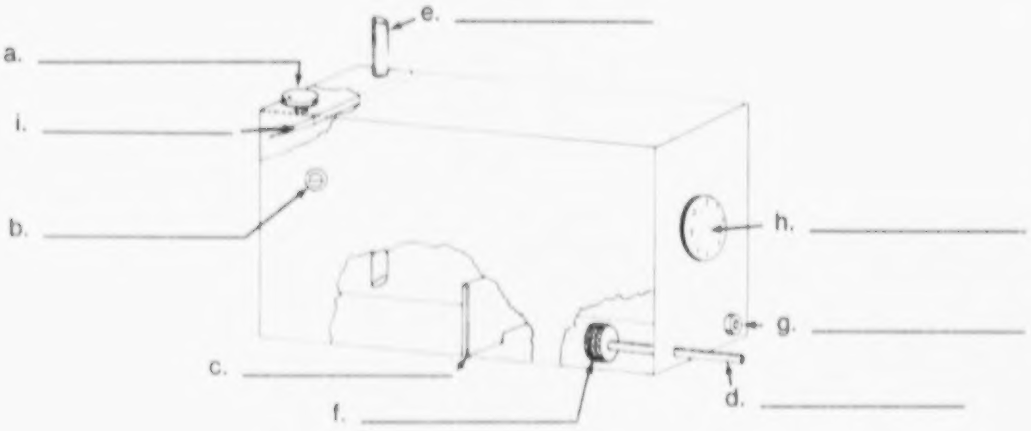
   ______d. Helps to separate dirt and air from fluid

   ______e. Provides mechanical action for movement of fluid

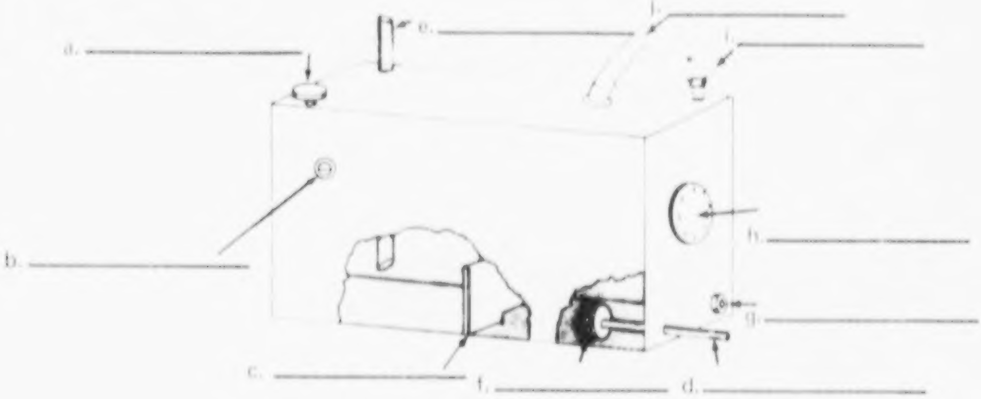
   ______f. Provides fluid to replace system leakage

TEST

5. Identify the parts of a properly designed, vented reservoir.



6. Identify the parts of a properly designed, pressurized reservoir.


a. ____________
e. ____________
j. ____________
i. ____________
b. ____________
h. ____________
g. ____________
c. ____________
f. ____________
d. ____________

TEST

7. Draw the symbols for reservoirs.

    a. Vented

    b. Pressurized

(NOTE: If the following activity has not been accomplished prior to the test, ask your instuctor when it should be completed.)

8. Demonstrate the ability to clean and inspect a vented reservoir.

RESERVOIRS
UNIT III

ANSWERS TO TEST

1. Container for holding a supply of fluid

2. a. Vented to atmosphere
   b. Pressurized and sealed

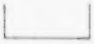
3. b, d, e

4. a, b, d, f

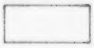
5. a. Filler cap
   b. Fluid level gauge
   c. Separation baffle
   d. Reservoir outlet
   e. Return line
   f. Intake filter screen
   g. Drain plug
   h. Inspection plate
   i. Pressure baffle

6. a. Filler cap
   b. Fluid level gauge
   c. Baffle
   d. Reservoir outlet
   e. Return line
   f. Intake filter screen
   g. Drain plug
   h. Inspection plate
   i. Pressure regulator
   j. Air line

7. a.



   b.



8. Performance skills evaluated to the satisfaction of the instructor

LINES, FITTINGS, AND COUPLERS

UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to select true statements concerning the characteristics of steel pipe and hydraulic hose and discuss the types, construction, and size of steel tubing. The student should also be able to identify hose-ends and fittings used in hydraulic systems and replace a reusable hose end. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student will be able to:

1. Match terms related to lines, fittings, and couplers with their correct definitions.
2. Select true statements concerning the characteristics of steel pipe.
3. Discuss the types, construction, and size of steel tubing.
4. Select true statements concerning the characteristics of hydraulic hose.
5. Identify types of fittings commonly used with tubing.
6. Identify types of hose-ends used in hydraulic systems.
7. Identify types of fittings used in hydraulic systems.
8. Select factors to consider when routing tubing in hydraulic systems.
9. List conditions to avoid when routing hydraulic hose.
10. Demonstrate the ability to replace a reusable hose end. (Job Sheet #1)

LINES, FITTINGS, AND COUPLERS
UNIT IV

SUGGESTED ACTIVITIES

A. Provide students with objective sheet.

B. Provide students with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheet.

G. Show students examples of lines, fittings, and couplers, and discuss safety precautions which should be practiced when working with them.

H. Give test.

CONTENTS OF THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

    1. TM 1 — Sizing of Steel Pipe
    2. TM 2 — Working Pressure for Steel Pipe
    3. TM 3 — Hose Construction and Hose Types
    4. TM 4 — Types of Fittings Commonly Used with Tubing
    5. TM 5 — Types of Hose Ends
    6. TM 6 — Types of Fittings Used in Hydraulic Systems
    7. TM 7 — Routing Hydraulic Hose and Tubing

D. Job Sheet #1 — Replace a Reusable Hose End

E. Test

F. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Fluid Power I.* Cleveland, OH: Parker-Hannifin Corporation, 1979.

B. *Fundamentals of Service.* Moline, IL: Deere and Company, 1967.

C. *Industrial Hydraulics Manual.* Troy, MI: Sperry Rand Corporation, 1970.

LINES, FITTINGS, AND RESERVOIRS
UNIT IV

INFORMATION SHEET

I. **Terms and definitions**

   A. Pipe — Rigid fluid conductor which is not intended to be bent or shaped

   B. Tubing — A semi-rigid fluid conductor which is customarily bent into a desired shape

   C. Hose — Flexible fluid conductor which can readily bend with movement of machine members

   D. Hose end — A fitting which is attached onto a hose to allow the hose to be connected to other components

   E. Fittings — A device for connecting hydraulic components, such as a hose to a valve

   F. Joint Industrial Council — An organization which is responsible for promotion of industrial standards

   (NOTE: JIC is the abbreviation for the Joint Industrial Council.)

   G. Skive — To remove the outer covering on a hose

II. **Characteristics of steel pipe**

   (NOTE: Do not use galvanized pipe in hydraulic systems.)

   A. Size (Transparency 1)

      1. Size typically specified by nominal inside diameter

      2. Wall thickness (for a given size) is described by a schedule number

   B. Pressure range (Transparency 2)

      1. Schedule 40 is commonly used for low pressure lines

      2. Schedule 80 is commonly used for high pressure lines

      3. Schedule 160 is commonly used for very high pressure lines

III. **Characteristics of steel tubing**

   A. Types

      1. Stainless

      2. Nonstainless

INFORMATION SHEET

B. Construction

1. Seamless
2. Welded

C. Size (Table 1)

TUBE OD	WALL THICKNESS	TUBE ID
1/8	0.028	0.069
	.032	.061
	.035	.055
3/16	0.032	0.1235
	.035	.1175

Table 1

1. Indicated by (actual) outside diameter and wall thickness
2. Wall thickness sometimes described as:
   a. Thin wall (low pressure)
   b. Standard (high pressure)
   c. Thick wall (very high pressure)

IV. Characteristics of hydraulic hose

A. Construction (Transparency 3)

1. Inner tube
2. Reinforcement
   a. Wire braid for high pressure applications
   b. Fiber braid for low pressure applications
3. Cover

B. Size

1. Factors to specify
   a. Inside diameter
   b. Working pressure
   c. Construction

INFORMATION SHEET

2. Standard hose types (Transparency 3)

    a. Standard developed by Society of Automotive Engineers (SAE)

    b. Hoses are guaranteed by the manufacturer to meet a minimum safety standard

V. **Types of fittings commonly used with tubing** (Transparency 4)

A. Flare (JIC 37° flare or 45° flare)

(NOTE: The end of the tubing is flared to mate with a fitting. 37° is most common and 45° is used in some low pressure applications.)

B. Flareless

1. Swage type

(NOTE: The tubing material is compressed to form a build-up of tubing material around a retaining ring. This ring is used to hold the fitting on the tubing.)

2. Bite type

(NOTE: A retaining ring is compressed onto the tube. The ring "bites" into the tubing. The primary difference between these two types of fittings is that the swage type displaces the tubing to conform around the retaining ring. The bite type cuts or bites into the tubing.)

C. Braze-on

(NOTE: The fitting is brazed or welded onto the end of the tubing.)

VI. **Types of hose-ends used in hydraulic systems** (Transparency 5)

A. Permanent

(NOTE: The fitting is crimped or swaged onto the hose.)

B. Reusable

1. No-skive

(NOTE: The hose cover is not removed. The hose-end nipple is inserted into the hose. A socket (sleeve) is screwed or pushed onto the hose-end to clamp it to the hose.)

2. Skive

(NOTE: The hose cover is removed (skived) prior to the installation of the hose end. The installation is the same as the no-skive.)

INFORMATION SHEET

3. Clamp-on

   (NOTE: A barbed hose-end nipple is inserted into hose and a clamp is bolted onto the hose to provide grip.)

4. JIC

VII. **Types of fittings used in hydraulic systems** (Transparency 6)

A. Pipe thread

B. Straight thread

(NOTE: Straight thread should be used with an O-ring.)

C. Flare

D. Split flange

VIII. **Factors to consider when routing tubing in hydraulic systems**

A. Avoid straight-line hook-ups

(NOTE: These do not allow expansion and contraction.)

B. Use the fewest and simplest bends possible

C. Support long runs of tubing

D. Avoid interference with operator controls

IX. **Conditions to avoid when routing hydraulic hose** (Transparency 7)

A. Taut hose

B. Loops

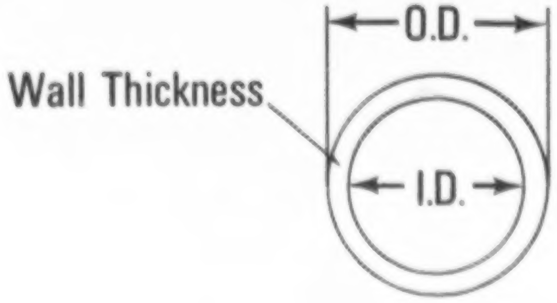
C. Twists

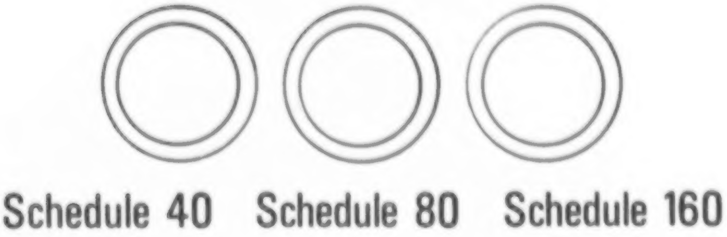
D. Rubbing

E. Heat

F. Sharp bends

Sizing of Steel Pipe


O.D.
Wall Thickness
I.D.


Schedule 40
Schedule 80
Schedule 160

Nominal Size	Pipe O.D.	INSIDE DIAMETER Schedule 40	Schedule 80	Schedule 160
⅛	.405	.269	.215	
¼	.540	.364	.302	
⅜	.675	.493	.423	
½	.840	.622	.564	.466
¾	1.050	.824	.742	.587
1	1.315	1.049	.957	.815
1¼	1.660	1.380	1.278	1.160
1½	1.900	1.610	1.500	1.338
2	2.375	2.067	1.939	1.689
2½	2.875	2.469	2.323	2.125
3	3.500	3.068	2.900	2.624

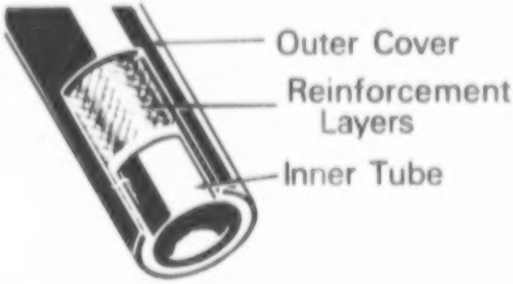
Working Pressure for Steel Pipe

Working Pressure (PSI)
(Burst Pressure)

Nominal Size	Schedule 40	Schedule 80	Schedule 160
1/8	3500 (20,200)	4800 (28,000)	—
1/4	2100 (19,500)	4350 (26,400)	—
3/8	1700 (16,200)	3800 (22,500)	—
1/2	2300 (15,600)	4100 (21,000)	7300 (26,700)
3/4	2000 (12,900)	3500 (17,600)	8500 (25,000)
1	2100 (12,100)	3500 (15,900)	5700 (22,300)
1 1/4	1800 (10,100)	3000 (13,900)	4400 (18,100)
1 1/2	1700 (9,100)	2800 (12,600)	4500 (17,700)
2	1500 (7,800)	2500 (11,000)	4600 (17,500)

Hose Construction and Hose Types

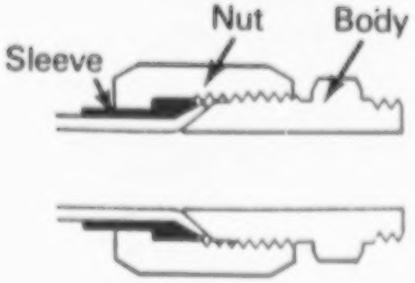
SAE Number	Inner Tube	Reinforcement	Cover
SAE 100R1	Synthetic Rubber	1 High Tensile Steel	Synthetic Rubber
SAE 100R2	Synthetic Rubber	2 Wire Braids 2 Spiral Plies and 1 Wire Braid	Synthetic Rubber
SAE 100R3	Synthetic Rubber	2 Textile Braids	Synthetic
SAE 100R4	Synthetic Rubber	Braided Textile Fibers/ Spiral Body Wire	Synthetic
SAE 100R5	Synthetic Rubber	1 Textile Braid a High Tensile Steel Wire Braid	Cotton Braid
SAE 100R6	Synthetic Rubber	1 Textile Braid	Synthetic Rubber
SAE 100R7	Thermoplastic	Synthetic Fiber	Thermoplastic
SAE 100R8	Thermoplastic	Synthetic Fiber	Thermoplastic
SAE 100R9	Synthetic Rubber	4 Spiral Plies Wrapped In Alternating Directions	Synthetic Rubber
SAE 100R10	Synthetic Rubber	4 Spiral Plies of Heavy Wire Wrapped in Alternating Directions	
SAE 100R11	Synthetic Rubber	6 Spiral Plies of Heavy Wire Wrapped in Alternating Directions	Synthetic Rubber



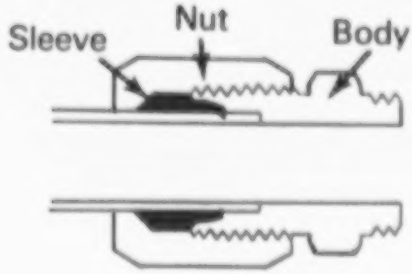
Flexible Hose Construction

SAE Hose Types

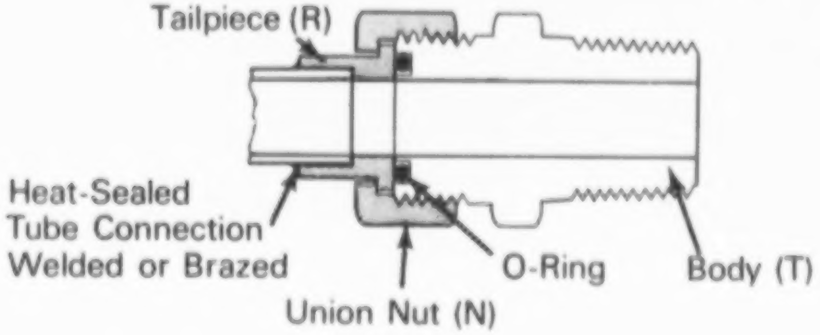
Types of Fittings Commonly Used with Tubing


Nut
Body
Sleeve

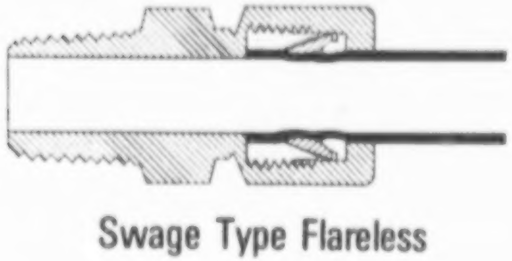
Flared


Nut
Sleeve
Body

Bite Type Flareless

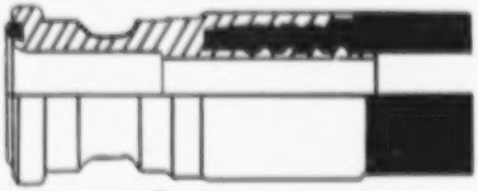

Tailpiece (R)
Heat-Sealed
Tube Connection
Welded or Brazed
Union Nut (N)
O-Ring
Body (T)

Braze-on

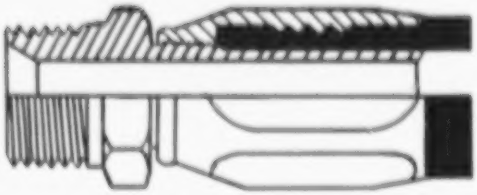


Swage Type Flareless

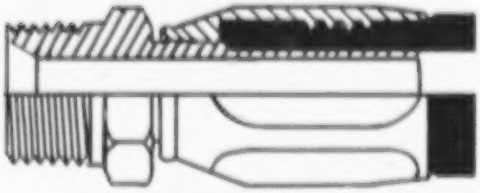
Types of Hose Ends



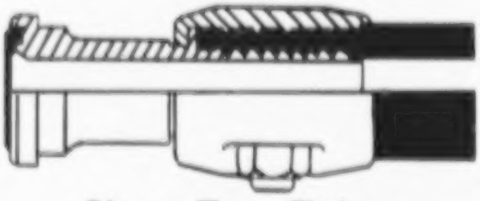
Permanent
Hose Fitting



Skive Fitting



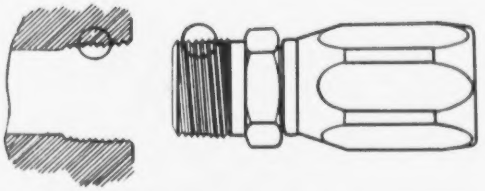
No-Skive Fitting



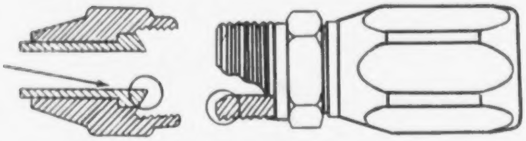
Clamp Type Fitting

Types of Fittings Used in Hydraulic Systems

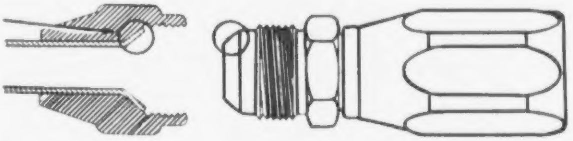
1. Pipe Thread (Tapered)



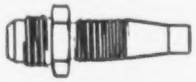
2. Dry Seal To 30° Cone Seat (Inverted Flare)



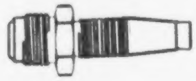
3. Flare Seal To Cone Seat



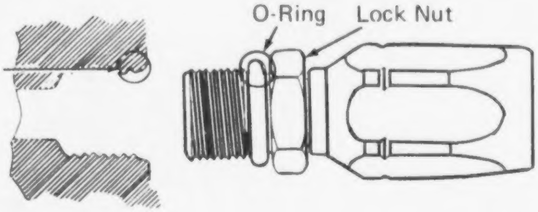
J.I.C. Flare Seal to 37° Cone Seat



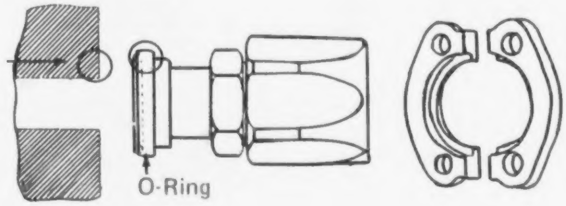
S.A.E. Flare Seal to 45° Cone Seat



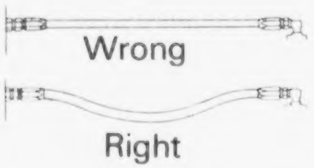
4. Straight Thread With O - Ring Seal



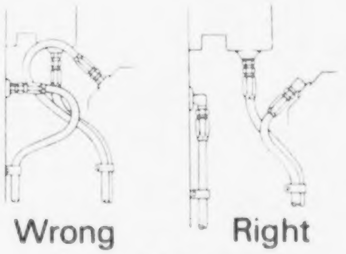
5. Split Flange O - Ring Seal



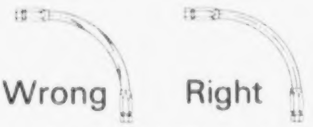
Routing Hydraulic Hose and Tubing


Wrong
Right

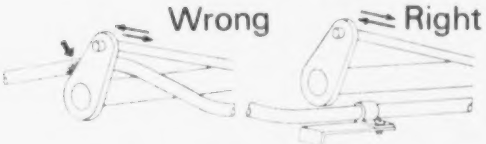
1. Avoid Taut Hose


Wrong
Right

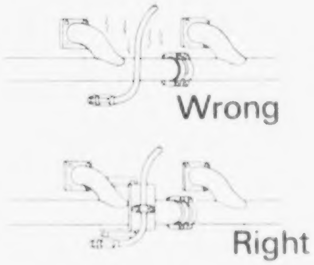
2. Avoid Loops


Wrong
Right

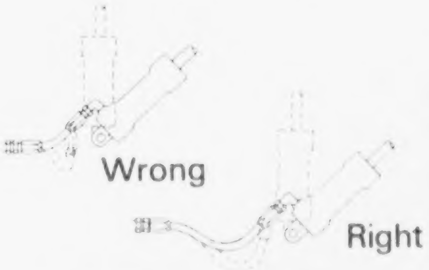
3. Avoid Twisting


Wrong
Right

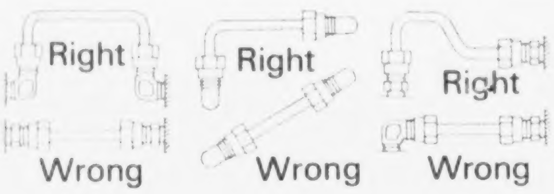
4. Avoid Rubbing


Wrong
Right

5. Avoid Heat


Wrong
Right

6.Avoid Sharp Bends


Right
Right
Right
Wrong
Wrong
Wrong

LINES, FITTINGS, AND COUPLERS
UNIT IV

JOB SHEET #1 — REPLACE A REUSABLE HOSE END

A. Tools and materials

1. Wrenches as required
2. Hose with reusable hose ends
3. Replacement hose

   (NOTE: Replacement hose must be matched to the hose ends.)
4. Tape measure
5. Tool to cut hose
6. Vise
7. Knife

B. Procedure

1. Remove the hose ends from the old hose

   (NOTE: For clamp on hose ends the screw should be removed and the two halves of the clamp are to be removed. The hose-end nipple can then be removed. For skive and non-skive hose-ends the socket (sleeve) should be pulled off or unscrewed as appropriate. The hose-end nipple can then be removed.)
2. Measure replacement hose and cut to length
3. If the hose end is a skive type, use the knife to remove the outer covering where the sleeve is to be placed on the hose
4. Lubricate the end of the hose and place the sleeve on the hose
5. Place the sleeve and hose assembly into the vise
6. Insert the nipple and screw it into the sleeve and hose assembly until the nipple seats againsts the sleeve
7. Repeat for the other end

☐ Have your instructor check your work

8. Clean up area and return tools and materials to proper storage

LINES, FITTINGS, AND COUPLERS
UNIT IV

NAME ______________________

TEST

1. Match the terms on the right with the correct definitions.

______a. Rigid fluid conductor which is not intended to be bent or shaped

______b. A semi-rigid fluid conductor which is customarily bent into a desired shape

______c. Flexible fluid conductor which can readily bend with movement of machine members

______d. A fitting which is attached onto a hose to allow the hose to be connected to other components

______e. A device for connecting hydraulic components, such as a hose to a valve

______f. An organization which is responsible for promotion of industrial standards

______g. To remove the outer covering on a hose

1. Fittings
2. Pipe
3. Skive
4. Hose
5. Joint Industrial Council
6. Tubing
7. Hose end

2. Select true statements concerning the characteristics of steel pipe by placing an "X" in the appropriate blanks.

______a. Size is typically specified by outside diameter

______b. Wall thickness is described by a schedule number

______c. Schedule 40 is commonly used for low pressure lines

______d. Schedule 160 is commonly used for very high pressure lines

______e. Schedule 80 is commonly used for low pressure lines

3. Discuss the characteristics of steel tubing.

a. Types

1) ____

2) ____

TEST

b. Construction

1) ______________________________

2) ______________________________

c. Size

1) ______________________________

2) ______________________________

a) ______________________________

b) ______________________________

c) ______________________________

4. Select true statements concerning the characteristics of hydraulic hose by placing an "X" in the appropriate blanks.

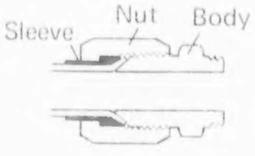
_____a. The construction of hydraulic hose consists of an inner tube, reinforcement of wire or fiber braid, and cover

_____b. Factors to specify size include outside diameter, working pressure, and construction

_____c. Standard hose types were developed by the Society of Automotive Engineers (SAE)

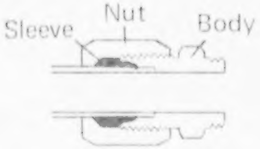
_____d. Hoses are guaranteed by the manufacturer to meet a minimum safety standard

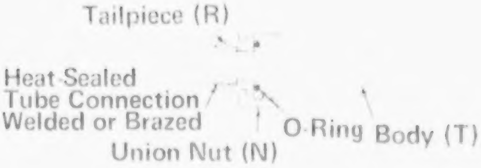
5. Identify the types of fittings commonly used with tubing.



a. ______________________ b. ______________________

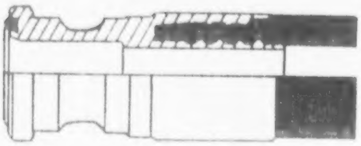
TEST

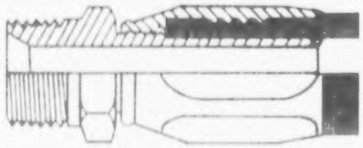

Sleeve
Nut
Body


Tailpiece (R)
Heat-Sealed
Tube Connection
Welded or Brazed
O-Ring
Body (T)
Union Nut (N)

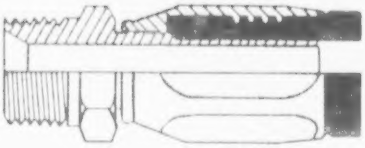
c. ______________________ d. ______________________

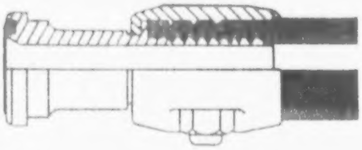
6. Identify types of hose-ends used in hydraulic systems.





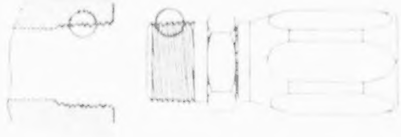
a. ______________________ b. ______________________

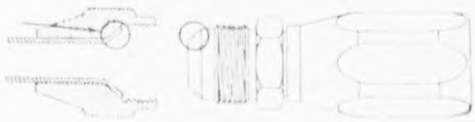




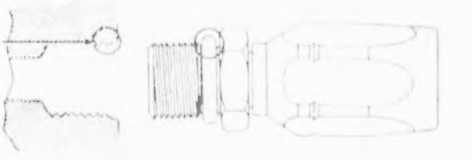
c. ______________________ d. ______________________

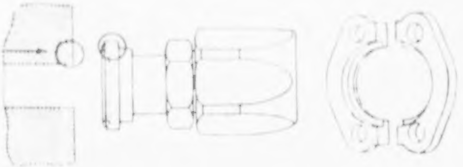
7. Identify types of fittings used in hydraulic systems.





a. ______________________ b. ______________________





c. ______________________ d. ______________________

TEST

8. Select factors to consider when routing tubing in hydraulic systems by placing an "X" in the appropriate blanks.

_____a. All hook-ups should be straight-line

_____b. Use as many bends as possible

_____c. Support long runs of tubing

_____d. Avoid interference with operator controls

9. List five conditions to avoid when routing hydraulic hose.

a. ____

b. ____

c. ____

d. ____

e. ____

(NOTE: If the following activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

10. Demonstrate the ability to replace a reusable hose end.

LINES, FITTINGS, AND COUPLERS
UNIT IV

ANSWERS TO TEST

1. a. 2
   b. 6
   c. 4
   d. 7
   e. 1
   f. 5
   g. 3

2. b, c, d

3. Discussion should include:
   a. Type
      1) Stainless
      2) Nonstainless
   b. Construction
      1) Seamless
      2) Welded
   c. Size
      1) Indicated by outside diameter and wall thickness
      2) Wall thickness sometimes described as:
         a) Thin wall
         b) Standard
         c) Thick wall

4. a, c, d

5. a. Flare
   b. Swage type flareless
   c. Bite type flareless
   d. Braze-on

6. a. Permanent
   b. Skive reusable
   c. No-skive reusable
   d. Clamp-on reusable

7. a. Pipe thread
   b. Flare
   c. Straight thread
   d. Split flange

8. c, d

9. Any five of the following:
   a. Taut hose
   b. Loops
   c. Twists
   d. Rubbing
   e. Heat
   f. Sharp bends

10. Performance skills evaluated to the satisfaction of the instructor

SEALS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to describe the leakage paths within a hydraulic system and match types of seals with their applications. The student should also be able to install an O-ring, a seal, and a packing. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student will be able to:

1. Match terms associated with seals with their correct definitions.
2. Describe two types of leakage paths in hydraulic systems.
3. Identify types of sealing devices used in hydraulic systems.
4. Match types of seals with their applications.
5. Identify types of seal construction.
6. Select factors to consider concerning seal material.
7. Demonstrate the ability to:
    a. Install an O-ring. (Job Sheet #1)
    b. Install a seal. (Job Sheet #2)
    c. Install a packing. (Job Sheet #3)

SEALS
UNIT V

SUGGESTED ACTIVITIES

A. Provide students with objective sheet.

B. Provide students with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Give test.

CONTENTS OF THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

    1. TM 1 — Typical Leakage Paths
    2. TM 2 — Types of Sealing Devices
    3. TM 3 — Types of Seal Construction
    4. TM 4 — Types of Seal Construction (Continued)
    5. TM 5 — Types of Seal Construction (Continued)

D. Job sheets

    1. Job Sheet #1 — Install an O-ring
    2. Job Sheet #2 — Install a Seal
    3. Job Sheet #3 — Install a Packing

E. Test

F. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Fluid Power I.* Cleveland, OH: Parker-Hannifin Corporation, 1979.

B. *Fundamentals of Service.* Moline, IL: Deere and Company, 1967.

C. *Industrial Hydraulics Manual.* Troy, MI: Sperry Rand Corporation, 1970.

SEALS
UNIT V

INFORMATION SHEET

I. **Terms and definitions**

   A. Sealing device — Any device which keeps hydraulic fluid from flowing between certain passages or keeps foreign material from entering the system

   B. Seal ring (seal) — A type of seal whose basic shape is a ring; may use various complex shapes to improve sealing characteristics

   C. O-ring — A simple seal with a round cross section

   D. Gasket — A thin flat seal sandwiched between two metal surfaces

   E. Packing — A seal with a square cross section or a seal with contoured layers for use with cylinder pistons

   F. Counter-bore — An enlarged area around a spool or shaft to allow room to accommodate a seal or O-ring

   G. Back-up ring — A ring installed behind an O-ring or seal to hold it in place

   H. Sealing compounds — Materials applied to machine surfaces to prevent leaks

II. **Types of leakage paths in hydraulic systems** (Transparency 1)

   A. Internal — Leakage from one compartment to another within a component

   B. External — Leakage from within the component to the outside

   (NOTE: Although leakage is generally considered undesirable, some leakage may be designed into the component. For example, some pumps have internal leakage paths to help cool the pump. Also, some seals allow a small amount of leakage to lubricate the seal.)

III. **Types of sealing devices** (Transparency 2)

   A. Seal

   B. Packing

   C. O-ring

   D. Back-up ring

   E. Gasket

INFORMATION SHEET

F. Sealing compounds

1. Liquid sealing compounds

2. Plastic or Teflon tape

(**CAUTION:** Teflon tape subject to high temperatures can release dangerous toxic fumes.)

IV. **Types of seals and their applications**

A. Static — Used where no mechanical movement occurs

B. Dynamic — Used where rotary or linear motion occurs

C. Wiper seal — Used to prevent dirt from entering the system

(NOTE: Wiper seals "wipe" dirt from a cylinder rod.)

V. **Types of seal construction** (Transparencies 3, 4, and 5)

A. T-ring seal

B. Lip seal

C. Cup seal

D. Face seal

E. Piston ring seal

VI. **Factors to consider concerning seal material**

A. Compatibility with the hydraulic fluid

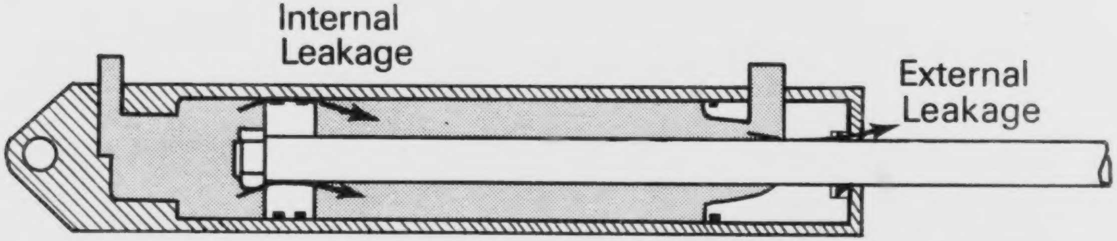
B. Temperature extremes

C. Exposure to environment

D. Wear characteristics

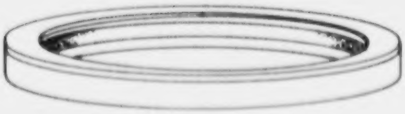
(NOTE: Improper hydraulic fluid, excessive temperature extremes, and sunlight may cause seal material to become hard or spongy. These conditions may cause the seal to fail to perform as desired.)

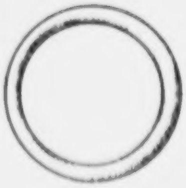
Typical Leakage Paths


Internal
Leakage
External
Leakage

Types of Sealing Devices

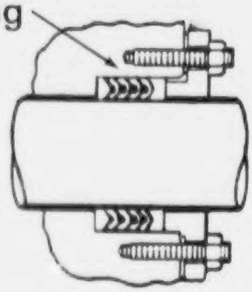
Seal



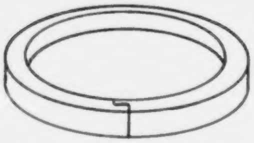


O-Ring

Chevron or V-Shaped Packing

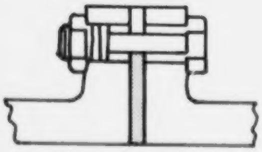


(Note: The Lip is Installed Towards Pressure.)

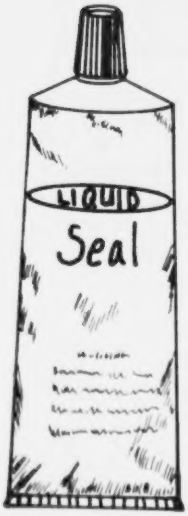


Back-up Ring

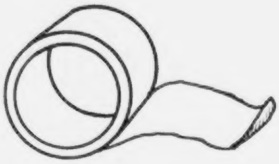
Gasket



Sealing Compounds



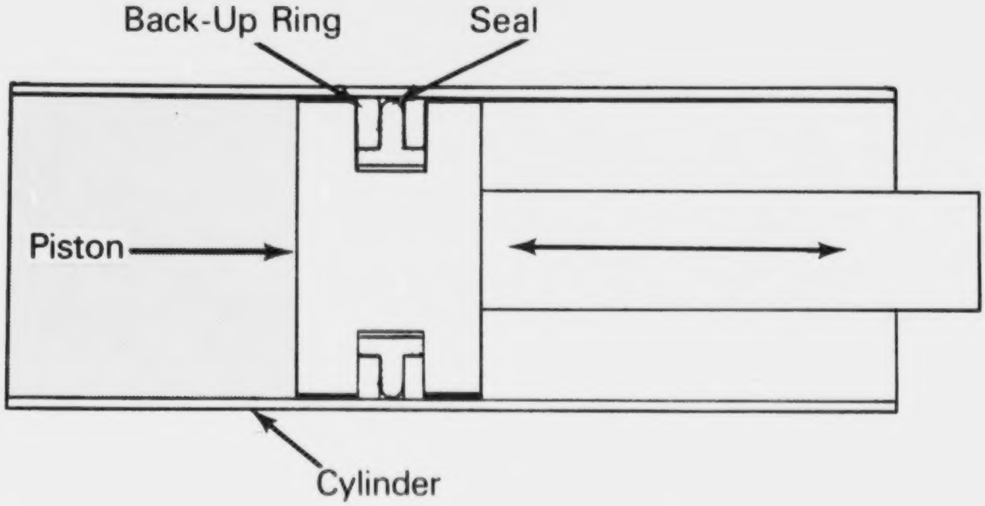
Liquids



Plastic or Teflon Tape

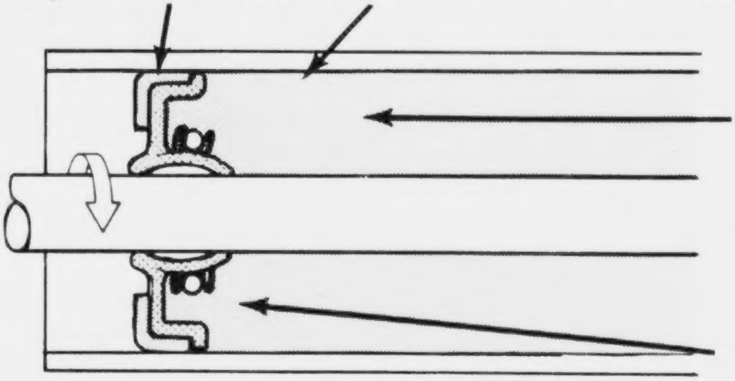
Types of Seal Construction

T-Ring Seal



A Stamped Housing Gives the Seal Rigidity and Facilitates Alignment at Installation.

The Lip is Formed of a Synthetic or Leather ; it is Installed Toward the Pressure Source.



Pressure Forces the Lip Tighter Around the Shaft to Aid Sealing.

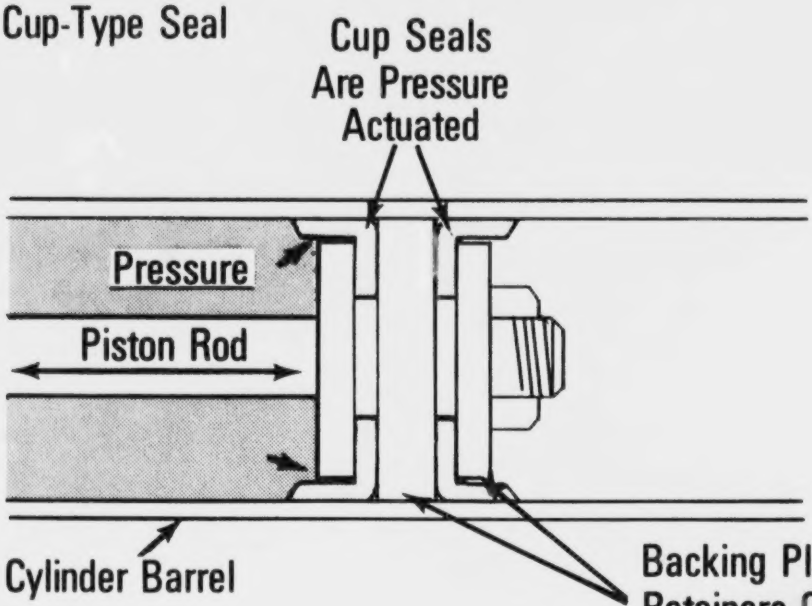
Spring Helps Sealing When There is No Pressure

Lip-Type Seal

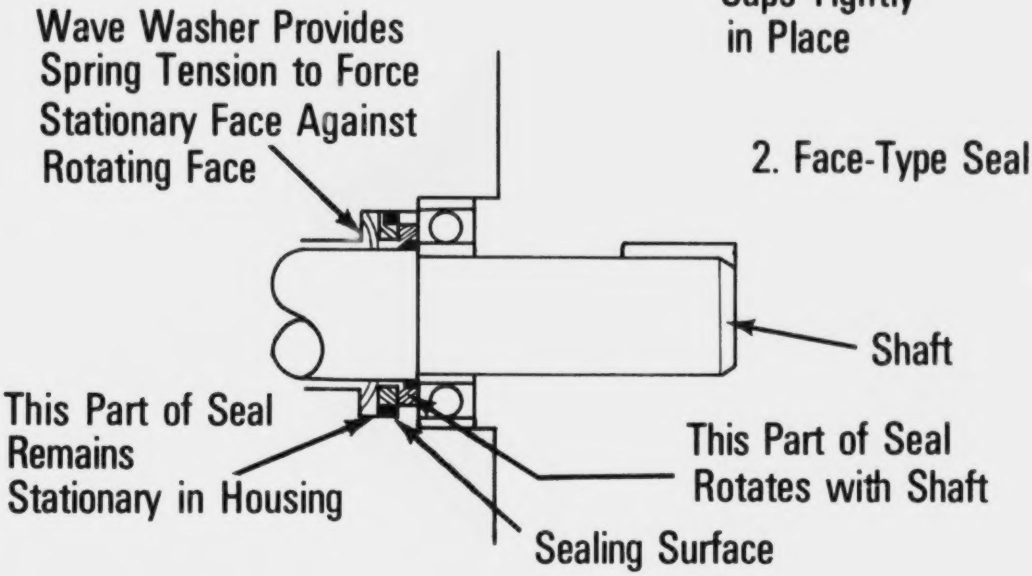
Types of Seal Construction

(Continued)

1. Cup-Type Seal


Cup Seals
Are Pressure
Actuated
Pressure
Piston Rod
Cylinder Barrel
Backing Plate and
Retainers Clamp
Cups Tightly
in Place

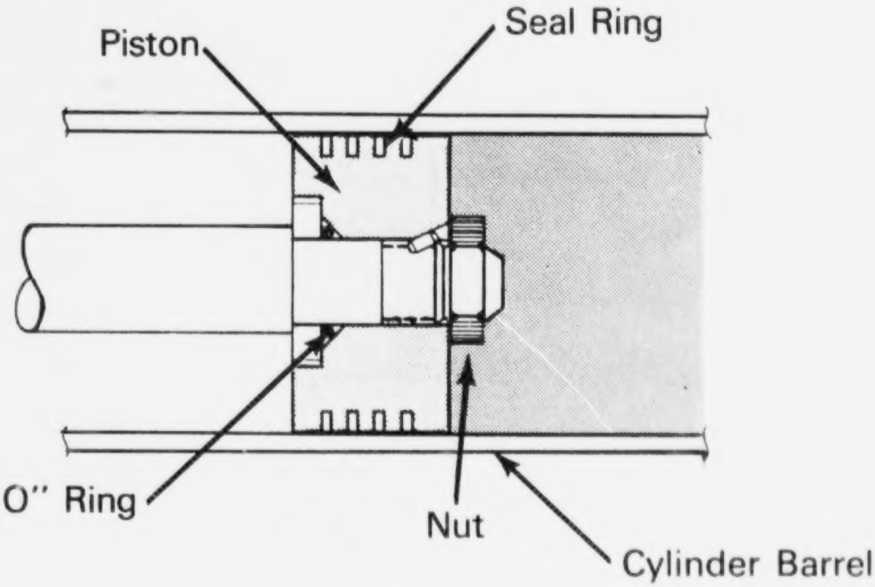
2. Face-Type Seal


Wave Washer Provides
Spring Tension to Force
Stationary Face Against
Rotating Face
Shaft
This Part of Seal
Remains
Stationary in Housing
This Part of Seal
Rotates with Shaft
Sealing Surface

Types of Seal Construction

(Continued)

Piston Ring Seal


Piston
Seal Ring
"O" Ring
Nut
Cylinder Barrel

SEALS
UNIT V

JOB SHEET #1 — INSTALL AN O-RING

A. Tools and materials

1. Wrenches as required
2. O-ring remover tool
3. Fitting assembly which uses an O-ring seal

   (NOTE: Other components which use O-ring seals may be used.)
4. O-ring of appropriate size
5. Abrasive material such as emery cloth

B. Procedure

1. Clean dirt and other foreign material from assembly
2. Disassemble fitting (or other component) to have access to the O-ring
3. Remove old O-ring
4. Inspect

   (NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
a. Inspect O-ring groove		
b. Remove sharp edges, nicks, or burrs with a find abrasive stone (NOTE: Extreme care should be taken with this operation.)		
c. Inspect shaft or spool for sharp edges		
d. Remove nicks or burrs with abrasive material		
e. Polish with a fine abrasive cloth		

5. Reclean assembly, removing any debris from above inspection

JOB SHEET #1

6. Install O-ring
    a. Lube O-ring
    b. Protect O-ring from sharp edges
    c. If necessary, cover sharp edges with a thin plastic shim during installation

       (NOTE: Avoid twisting O-ring during installation.)
7. Reassemble
    a. Align parts and reassemble
    b. During reassembly, observe that the O-ring is properly seated and not cut or twisted

       (NOTE: Only a slight squeeze should be applied to the O-ring. Normally, the component will be cycled for a few cycles and then visually inspected for leakage. This operation will not be performed at this time.)

☐ Have your instructor check your work

8. Clean up area and return tools and materials to proper storage

SEALS
UNIT V

JOB SHEET #2 — INSTALL A SEAL

A. Tools and materials

1. Wrenches as required
2. Seal installation tool (if required)
3. Cylinder which uses a wiper seal
4. Wiper seal
5. Abrasive material such as emery cloth

B. Procedure

(NOTE: This procedure may also be used for pressure type seals.)

1. Clean cylinder rod and end cap
2. Remove end cap
3. Remove old seal
4. Clean shaft and bore of cylinder
5. Inspect

   (NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
a. Check shaft for nicks and burrs		
b. Repair damaged area with abrasive material		
c. Polish with fine emery cloth		
d. Reclean		

6. Lubricate seal with recommended fluid to ease installation

JOB SHEET #2

7. Load seal onto shaft
    a. Use plastic shim to protect seal from sharp edges
    b. Insure that the seal is oriented properly
8. Cost outside diameter of metal cased seals with gasket cement to prevent leakage
9. Seat seal

   (NOTE: Press-fit seals may require the use of a special tool to press the seal in place.)
10. Insure that the seal is securely installed
11. Reinstall end cap

    (NOTE: Normally, the cylinder will be cycled for a few cycles then visually inspected for leakage. This operation will not be performed at this time.)

☐ Have your instructor check your work

12. Clean up area and return tools and materials to proper storage

SEALS
UNIT V

JOB SHEET #3 — INSTALL A PACKING

A. Tools and materials

1. Wrenches as required
2. Pump or other component which uses a seal
3. Packings
4. Abrasive material such as emery cloth

B. Procedure

1. Remove the gland or ring which retains the packs
2. Remove old packings
3. Inspect the shaft surface
4. Remove any nicks or scratches with the abrasive material
5. Soak the packing in hydraulic oil prior to installation
6. Install packings with the cup or V portion toward the pressure

   (NOTE: Packs which are composed of individual rings should be installed with each rotated 180° from the last ring.)

7. Re-install the gland or retaining ring
8. Tighten only enough to prevent leakage

☐ Have your instructor check your work

9. Clean up area and return tools and materials to proper storage

SEALS
UNIT V

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Any device which keeps hydraulic fluid from flowing between certain passages or keeps foreign material from entering the system

_____b. A type of seal whose basic shape is a ring; may use various complex shapes to improve sealing characteristics

_____c. A simple seal with a round cross section

_____d. A thin flat seal sandwiched between two metal surfaces

_____e. A seal with a square cross section or a seal with contoured layers for use with cylinder pistons

_____f. An enlarged area around a spool or shaft to allow room to accommodate a seal or O-ring

_____g. A ring installed behind an O-ring or seal to hold it in place

_____h. Materials applied to machine surfaces to prevent leaks

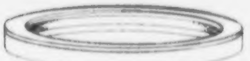
1. Gasket
2. Packing
3. Sealing device
4. O-ring
5. Seal ring
6. Counter-bore
7. Back-up ring
8. Sealing compounds

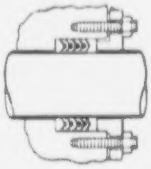
2. Describe two types of leakage paths in hydraulic systems.

a. Internal — ______________________________

b. External — ______________________________

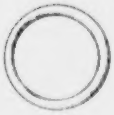
3. Identify types of sealing devices used in hydraulic systems.



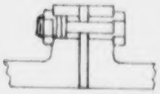


a. ____________________ b. ____________________

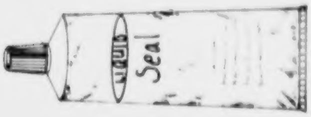
TEST



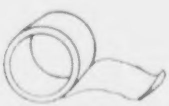
c. ______________________________



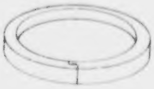
d. ______________________________



e. ______________________________



f. ______________________________



g. ______________________________

4. Match the types of seals on the right with their applications.

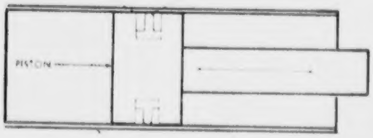
_____a. Used to prevent dirt from entering the system

_____b. Used where no mechanical movement occurs

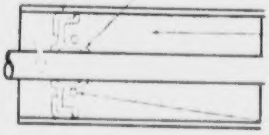
_____c. Used where rotary or linear motion occurs

1. Static
2. Wiper seal
3. Dynamic

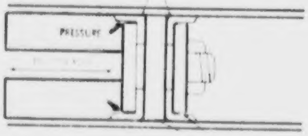
5. Identify types of seal construction.



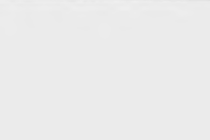
a. ______________________



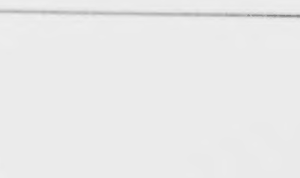
b. ______________________



c. ______________________



d. ______________________________



e. ______________________________

TEST

6. Select factors to consider concerning seal material by placing an "X" in the appropriate blanks.

   ______a. Temperature extremes

   ______b. Wear characteristics

   ______c. Noise conditions

   ______d. Dynamic elasticity

   ______e. Compatibility with the hydraulic fluid

   ______f. Exposure to environment

   ______g. Pressure of components

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

7. Demonstrate the ability to:

   a. Install an O-ring.

   b. Install a seal.

   c. Install a package.

SEALS
UNIT V

ANSWERS TO TEST

1. a. 3
   b. 5
   c. 4
   d. 1
   e. 2
   f. 6
   g. 7
   h. 8

2. Description should include:
   a. Leakage from one compartment to another within a component
   b. Leakage from within the component to the outside

3. a. Seal
   b. Packing
   c. O-ring
   d. Gasket
   e. Liquid sealing compound
   f. Plastic or Teflon
   g. Back-up ring

4. a. 2
   b. 1
   c. 3

5. a. T-ring
   b. Lip seal
   c. Cup seal
   d. Face seal
   e. Piston ring seal

6. a, b, e, f

7. Performance skills evaluated to the satisfaction of the instructor

FLUIDS AND FILTERS

UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to select the effects of contaminants and functions of filters in a hydraulic system and list functions of the fluid in a hydraulic system. The student should also be able to match the locations to the types of filters in the hydraulic system and identify types of filter circuits. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with fluids and filters with their correct definitions.
2. Select the effects of contaminants in the hydraulic system.
3. List practices for assuring hydraulic system cleanliness.
4. Select functions of the filter in a hydraulic system.
5. Distinguish between surface filters and depth filters.
6. Match the locations with the types of filters in the hydraulic system.
7. Identify types of filter circuits.
8. Select factors used in specifying a filter.
9. Draw the symbol for a filter.
10. List four functions of the fluid in hydraulic systems.
11. Select true statements concerning the effect of temperature on the viscosity of hydraulic fluids.
12. Name common additives in hydraulic systems.
13. List six safety rules to remember when working with hydraulic fluid.

FLUIDS AND FILTERS
UNIT VI

SUGGESTED ACTIVITIES

A. Provide students with objective sheet.

B. Provide students with information sheet.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Show students types of filters.

G. Disassemble filter to show functions of filters.

H. Give test.

CONTENTS OF THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

  1. TM 1 — Types of Filters
  2. TM 2 — Locations of Filters in Hydraulic System
  3. TM 3 — Types of Filter Circuits

D. Test

E. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Fundamentals of Service, Hydraulics.* Moline, IL: John Deere and Company, 1967.

B. Pippinger, John, and Tyler Hicks. *Industrial Hydraulics.* New York: McGraw-Hill Book Company, 1979.

C. *Fluid Power Designer's Lightning Reference Handbook.* Orange, CA: Paul-Munroe Hydraulics, Inc., 1976.

FLUIDS AND FILTERS
UNIT VI

INFORMATION SHEET

I. **Terms and definitions**

A. Contaminant — Any unwanted material in the hydraulic system

(NOTE: This includes various chemicals and particles such as metal, rust, sand, and water which is the most common frequent contaminant.)

B. Particulate contaminant — Contaminants which is composed of particles

C. Filter — A device which removes contaminants from hydraulic systems

D. Strainer — A very coarse filter typically used to prevent large items such as rocks and bolts from entering the system

E. Viscosity — A measure of the fluid's resistance to flow

(NOTE: The viscosity will vary as temperature varies.)

F. Micron — A measure of size equal to one millionth of a meter

(NOTE: Micron size is often used to describe the size of particles which a filter will remove from the fluid. For example, a 10 micron absolute filter is designed to remove all particles greater than 10 microns.)

II. **Effects of contaminants in the hydraulic system**

(NOTE: One teaspoon of dust in 55 gallons of oil constitutes a dirty system.)

A. Reduced component life

(NOTE: Even small amounts of contaminant in the system may wear out a hydraulic pump in as little as a few hours.)

B. Scored internal surfaces

(NOTE: Scored internal surfaces can result in excess leakage and poor performance.)

C. Clogged internal passages

D. Seized components

E. Poor performance

F. Improper operation

INFORMATION SHEET

III. **Practices for assuring hydraulic system cleanliness**

A. Change fluid and filter regularly

B. Fill system only with clean oil

(NOTE: Factory fresh oil is often quite dirty.)

C. Clean dirt off breather caps and filler plugs prior to opening system

D. Use a clean, lint-free towel to wipe dipstick

E. Replace worn seals

(NOTE: Worn wiper seals on cylinders can allow a large amount of dirt to enter the system through the cylinder.)

F. Keep work area clean

(NOTE: This is especially important when disassembling components such as pumps.)

G. Clean and flush components prior to installing in system

IV. **Functions of the filter in a hydraulic system**

A. To remove dirt that has entered the system through breather caps, seals, open lines, and unclean components

B. To remove metal particles generated by wear processes

C. To remove particles resulting from rust or corrosion of internal surfaces

V. **Types of filters** (Transparency 1)

A. Surface filter — Has a single surface that catches and removes dirt particles larger than the holes in the filter

B. Depth filter — Uses a large volume of filter material to trap the particles as the oil passes through

(NOTE: This filter material is similar to cotton.)

VI. **Locations of filters in the hydraulic system** (Transparency 2)

A. Strainer or suction line filter — Inlet of the pump

(NOTE: An inlet strainer is used only to prevent objects such as nuts, bolts, and metal chips from entering the pump.)

B. Pressure line filter — Outlet of the pump

C. Return line filter — Return line between outlet of load and reservoir

INFORMATION SHEET

VII. **Types of filter circuits** (Transparency 3)

A. Full flow filter

B. Partial flow filter

C. Auxiliary flow filter

VIII. **Factors used in specifying a filter**

A. Degree of filtration (performance)

(NOTE: This is commonly expressed as an efficiency or as minimum size particle removed.)

B. Flow rate

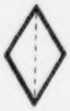
C. Pressure drop

D. Dirt capacity

E. System pressure

F. Operating temperature

IX. **Symbol for a filter**



(NOTE: This symbol is also used for a strainer.)

X. **Functions of the fluid in hydraulic systems**

A. Transmit power

B. Lubricate system

C. Assist in sealing system

D. Transport heat

XI. **Effect of temperature on the viscosity of hydraulic fluids**

A. Viscosity will decrease as temperature increases

B. Viscosity will increase as temperature decreases

C. The amount of change in viscosity for a specified change in temperature is known as the viscosity index

D. Some new hydraulics fluids are multi-viscosity and function well in almost all temperature ranges

INFORMATION SHEET

XII. **Common additives in hydraulic systems**

A. Viscosity index improver to keep oil at a consistent viscosity in extremes of heat and cold

B. Anti-wear additives

C. Anti-oxidation compounds

D. Corrosion inhibitors

E. Anti-foam additives

XIII. **Safety rules to remember when working with hydraulic fluids**

A. Allow the system to cool prior to working on it

(NOTE: Fluid in a working hydraulic system will commonly be in the temperature range of 150°F to 225°F or even higher. These temperatures can cause severe burns.)

B. Avoid contact with skin and eyes

(NOTE: Some hydraulic fluids are very caustic, particularly aircraft fluids.)

C. Remove filter cap slowly to relieve any trapped pressure

(NOTE: Some systems are capable of pressure build up in the reservoir from thermal expansion of the fluid caused by a hot day. It is possible that you may be sprayed with oil if the pressure is not slowly released.)

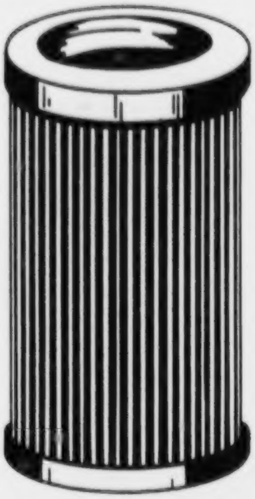
D. Since many hydraulic fluids are flammable, treat all fluids as flammable materials

(NOTE: Most hydraulic fluids used on mobile equipment are flammable.)

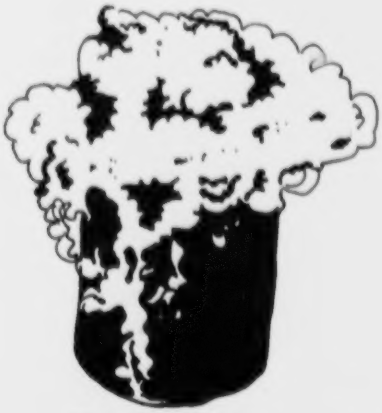
E. Avoid contact with hot objects such as exhaust manifolds

F. Wear safety glasses when entering a hydraulic system at any point

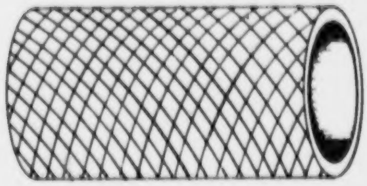
Types of Filters



Surface Filter
(Wire Mesh Filter)

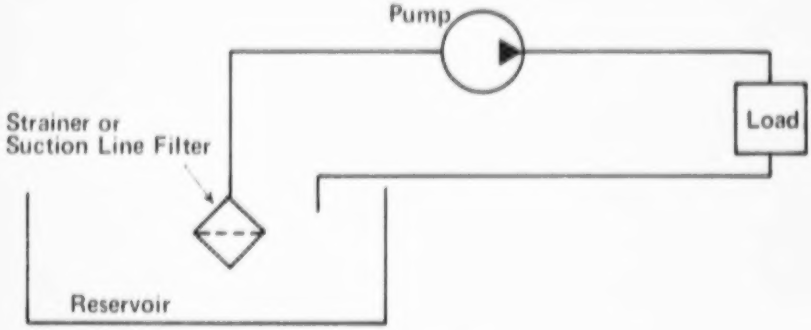


Depth Filter
(Cotton Waste Filter)

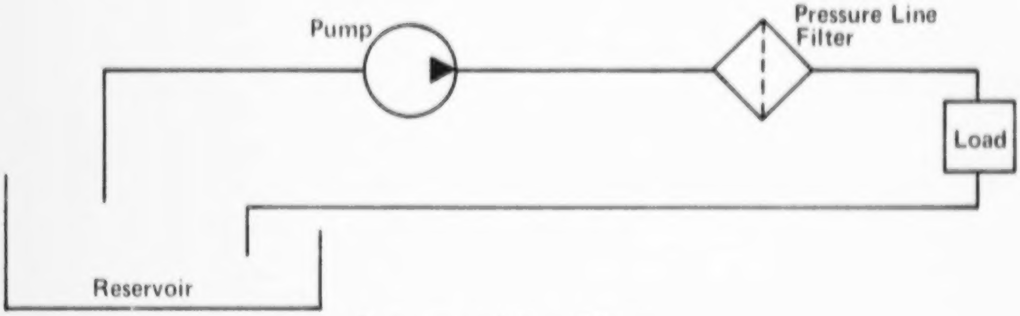


Strainer Filter

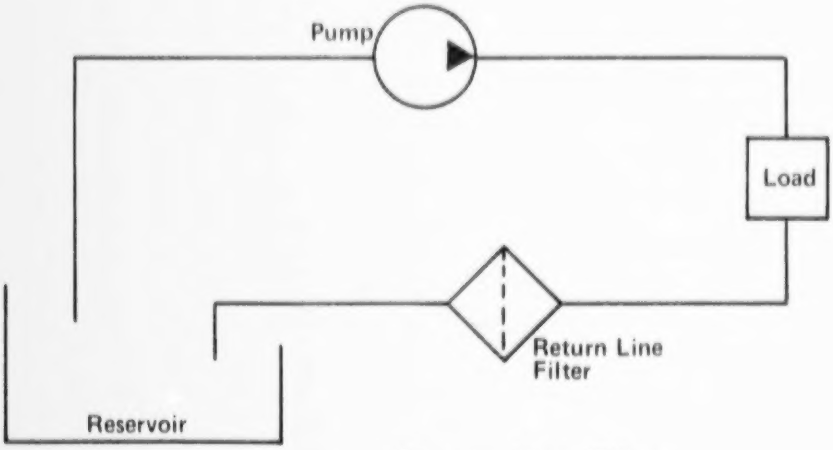
Location of Filters in Hydraulic System


Pump
Load
Strainer or
Suction Line Filter
Reservoir

Strainer or Suction Line Filter

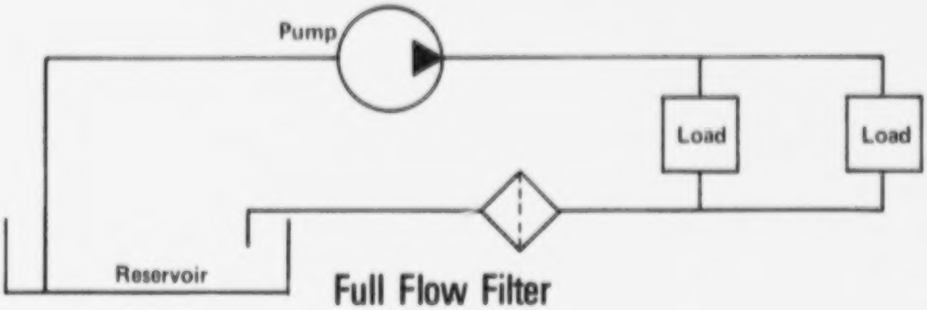

Pump
Pressure Line
Filter
Load
Reservoir

Pressure Line Filter

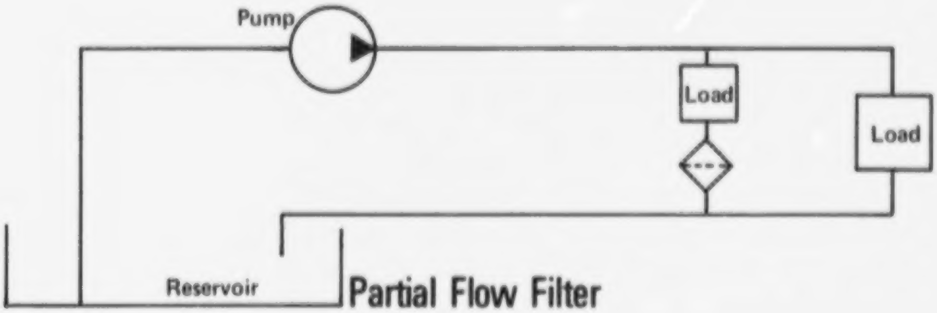

Pump
Load
Return Line
Filter
Reservoir

Return Line Filter

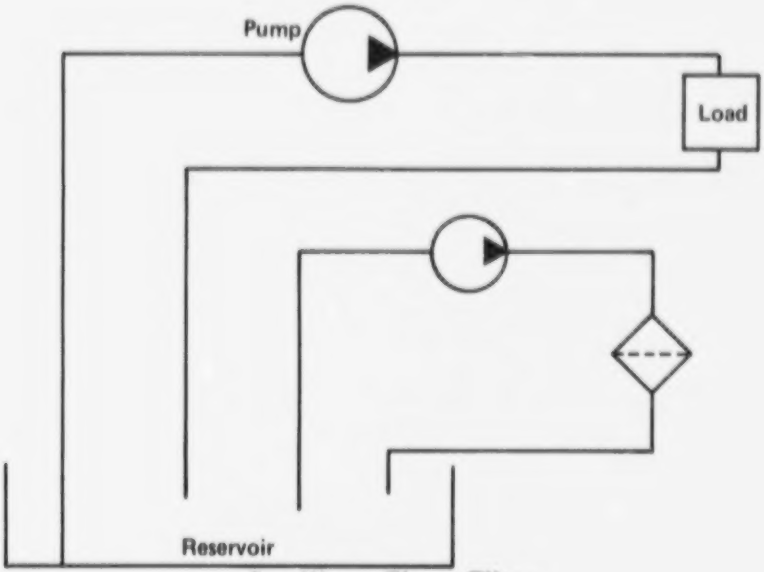
Types of Filter Circuits


Pump
Load
Load
Reservoir

Full Flow Filter


Pump
Load
Load
Reservoir

Partial Flow Filter


Pump
Load
Reservoir

Auxiliary Flow Filter

FLUIDS AND FILTERS
UNIT VI

NAME ______________________

TEST

1. Match the terms on the right with the correct definitions.

______a. Any unwanted material in the hydraulic system

______b. Contaminant which is composed of particles

______c. A device which removes contaminants from hydraulic systems

______d. A very coarse filter typically used to prevent large items such as rocks and bolts from entering the system

______e. A measure of the fluid's resistance to flow

______f. A measure of size equal to one millionth of a meter

1. Strainer
2. Contaminant
3. Viscosity
4. Filter
5. Micron
6. Particulate contaminant

2. Select the effects of contaminants in the hydraulic system by placing an "X" in the appropriate blanks.

______a. Clogged internal passages

______b. Better performance

______c. Smooth internal surfaces

______d. Improper operation

______e. Reduced component life

______f. Better availability of parts

______g. Scored internal surfaces

______h. Seized components

TEST

3. List five practices for assuring hydraulic system cleanliness.

a. ____

b. ____

c. ____

d. ____

e. ____

4. Select functions of the filter in a hydraulic system by placing an "X" in the appropriate blanks.

______a. To remove rocks and bolts in the hydraulic fluid

______b. To remove particles resulting from rust or corrosion of internal surfaces

______c. To remove water in the oil

______d. To remove metal particles generated by wear processes

______e. To remove dirt that has entered the system through breather caps, seals, open lines, and unclean components

5. Distinguish between surface filters and depth filters by placing an "X" next to the description of depth filters.

______a. Has a single surface that catches and removes dirt particles larger than the holes in the filter

______b. Uses a large volume of filter material to trap the particles as the oil passes through

6. Match the locations of filters in the hydraulic system with the correct filters.

______a. Pressure line filter

______b. Return line filter

______c. Strainer or suction line filter

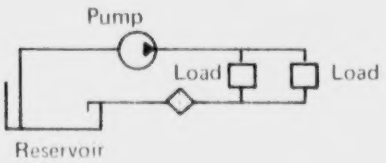
1. Inlet of the pump

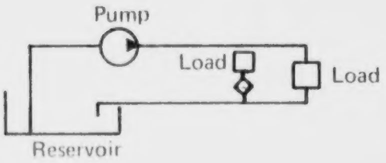
2. Outlet of the pump

3. Return line between outlet of load and reservoir

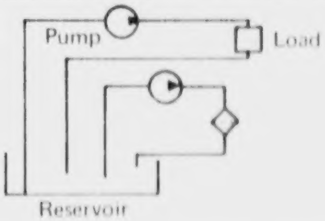
TEST

7. Identify types of filter circuits.


Pump
Load
Load
Reservoir


Pump
Load
Load
Reservoir

a. ______________________________ b. ______________________________


Pump
Load
Reservoir

c. ______________________________

8. Select factors used in specifying a filter by placing an "X" in the appropriate blanks.

_____a. Degree of filtration

_____b. Flow rate

_____c. Water pressure

_____d. Dirt capacity

_____e. Pressure drop

_____f. Size of hydraulic lines

_____g. System pressure

_____h. Amount of water in the oil

_____i. Operating temperature

9. Draw the symbol for a filter.

TEST

10. List four functions of the fluid in hydraulic systems.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

11. Select true statements concerning the effect of temperature on the viscosity of hydraulic fluids by placing an "X" in the appropriate blanks.

_____a. Viscosity will decrease as temperature increases

_____b. Viscosity will increase as temperature increases

_____c. Viscosity will decrease as temperature decreases

_____d. Viscosity will increase as temperature decreases

_____e. The amount of change in viscosity for a specified change in temperature is known as the viscosity index

_____f. Some new hydraulic fluids are multi-viscosity and function well in almost all temperature ranges

12. Name three common additives in hydraulic systems.

a. ____________________

b. ____________________

c. ____________________

13. List six safety rules to remember when working with hydraulic fluids.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

FLUIDS AND FILTERS
UNIT VI

ANSWERS TO TEST

1. a. 2 d. 1
   b. 6 e. 3
   c. 4 f. 5

2. a, d, e, g, h

3. Any five of the following:
   a. Change fluid and filter regularly
   b. Fill system only with clean oil
   c. Clean dirt off breather caps and filler plugs prior to opening system
   d. Use a clean, lint-free towel to wipe dipstick
   e. Replace worn seals
   f. Keep work area clean
   g. Clean and flush components prior to installing in system

4. b, d, e

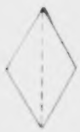
5. b

6. a. 2
   b. 3
   c. 1

7. a. Full flow filter
   b. Partial flow filter
   c. Auxiliary flow filter

8. a, b, d, e, g, i

9.



10. a. Transmit power
    b. Lubricate system
    c. Assist in sealing system
    d. Transport heat

11. a, d, e, f

ANSWERS TO TEST

12. Any three of the following:
    a. Viscosity index improver
    b. Anti-wear additives
    c. Anti-oxidation compounds
    d. Corrosion inhibitors
    e. Anti-foam additives

13. a. Allow the system to cool prior to working on it
    b. Avoid contact with skin and eyes
    c. Remove filter cap slowly to relieve any trapped pressure
    d. Since many hydraulic fluids are flammable, treat all fluids as flammable material
    e. Avoid contact with hot objects such as exhaust manifolds
    f. Wear safety glasses when entering a hydraulic system at any point

PUMPS
UNIT VII

UNIT OBJECTIVE

After completion of this unit, the student should be able to calculate pump displacement, flow rate, input and output power, and pump volumetric efficiency. The student should also be able to discuss the operation of a gear pump, and axial piston pump, and select true statements concerning the operation of vane pumps. The student should also be able to disassemble, inspect, and reassemble a gear pump and a pressure compensated pump. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to pumps with their correct definitions.
2. Distinguish between positive and nonpositive displacement pumps.
3. Name kinds of positive displacement pumps.
4. Given the formula, calculate pump displacement.
5. Given the formula, calculate pump flow rate.
6. Given the formulas, calculate pump input and output power.
7. Calculate pump volumetric efficiency.
8. Discuss the operation of a gear pump.
9. Select true statements concerning the operation of vane pumps.
10. Distinguish between an axial and a radial piston pump.
11. Select true statements concerning the operation of a radial piston pump.
12. Name two types of axial piston pumps.
13. Discuss the construction and operation of axial piston pumps.

OBJECTIVE SHEET

14. Select true statements concerning the operation of a variable displacement axial piston pump.

15. Identify the parts of a servo-controlled variable displacement pump.

16. Match the components of pressure compensated axial piston pumps with their functions.

17. List four causes of hydraulic pump cavitation.

18. List common causes of hydraulic pump failure.

19. Draw the symbols for types of pumps.

20. Demonstrate the ability to:

    a. Disassemble, inspect, and reassemble a gear pump. (Job Sheet #1)

    b. Disassemble, inspect, and reassemble a pressure compensated variable displacement pump. (Job Sheet #2)

PUMPS
UNIT VII

SUGGESTED ACTIVITIES

A. Provide students with objective sheet.

B. Provide students with information, assignment, and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the assignment and job sheets.

G. Show students different types of pumps and demonstrate their operation.

H. Give test.

CONTENTS OF THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

  1. TM 1 — Gear Pump
  2. TM 2 — Vane Pumps
  3. TM 3 — Types of Piston Pumps
  4. TM 4 — Construction and Operation of Axial Piston Pumps
  5. TM 5 — Bent-Axis Axial Piston Pump — Fixed Displacement
  6. TM 6 — Operation of Variable Displacement Axial Piston Pump
  7. TM 7 — Parts of a Servo-Controlled Variable Displacement Pump
  8. TM 8 — Operation of Pressure Compensated Axial Piston Pumps

D. Assignment Sheet #1 — Calculate Pump Displacement, Flow Rate, Input and Output Power, and Overall Efficiency

E. Answers to assignment sheet

CONTENTS OF THIS UNIT

F. Job sheets

  1. Job Sheet #1 — Disassemble, Inspect, and Reassemble a Gear Pump

  2. Job Sheet #2 — Disassemble, Inspect, and Reassemble a Pressure Compensated Variable Displacement Pump

G. Test

H. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Fundamentals of Service, Hydraulics.* Moline, IL: John Deere and Company, 1967.

B. *Industrial Hydraulics Manual* 935100-A. Troy, MI: Sperry-Rand Corporations, 1970.

C. *Fluid Power 1.* Cleveland, OH 44112: Parker-Hannifin Corporation, 1975.

PUMPS
UNIT VII

INFORMATION SHEET

I. **Terms and definitions**

   A. Pump — A device which creates the flow of fluid

   B. Displacement — The volume of fluid which is transferred from the pump inlet to the outlet during one revolution of the pump

   C. Volumetric efficiency — The actual flow rate from a pump divided by the theoretical flow rate

   (NOTE: The theoretical flow rate is calculated using $Q - n \times d/231$ where Q is the theoretical flow rate, n is the speed in revolutions per minute, and d is the displacement in cubic inches. Efficiency is often expressed as a percentage.)

   D. Cavitation — The formation of air bubbles in the inlet of a pump because the inlet does not completely fill with fluid

   E. Aeration — Air in the fluid

   F. Back pressure — Pressure in the return line caused by flow through the line from the pump to the reservoir

II. **Types of pumps**

   A. Positive displacement — A pump whose inlet is sealed from the outlet; will deliver fluid any time the inlet is kept supplied and the pump is driven

   B. Nonpositive displacement — A pump whose inlet and outlet are hydraulically connected so that the fluid can recirculate in the pump when pressure builds up

III. **Kinds of positive displacement pumps**

   A. Gear

   B. Vane

   C. Piston

   D. Screw

INFORMATION SHEET

IV. **Formula for calculation of pump displacement**

$$d = \frac{231Q}{n}$$

where d = displacement in in^3/revolution
Q = pump outlet flow rate in gallons per minute (GPM)
n = pump speed in revolutions per minute (RPM)

Example: A pump which has an outlet flow of 20 GPM at 1800 RPM has a displacement of 2.56 in^3/rev

$$d = \frac{231 \times 20\ \text{GPM}}{1800\ \text{RPM}} = 2.56\ \text{in}^3/\text{rev}$$

V. **Formula for calculation of pump flow rate**

$$Q = \frac{n \times d}{231}$$

Example: A 2.56 in^3/rev. pump operating at 2400 RPM has a flow rate of 26.6 GPM

$$Q = \frac{2400 \times 2.56}{231} = 26.6\ \text{GPM}$$

VI. **Formula for calculation of pump power**

A. Output power

$$\text{Power} = \frac{P \times Q}{1714}$$

where Power = Output power in horsepower
P = Outlet pressure in PSI
Q = Outlet flow in GPM

Example: A pump operating with 20 GPM flow and 3000 PSI outlet pressure has output power of 35 HP

$$\text{Power} = \frac{3000\ \text{PSI} \times 20\ \text{GPM}}{1714} = 35\ \text{HP}$$

INFORMATION SHEET

B. Input power

$$\text{Power} = \frac{n \times \text{Torque}}{5252}$$

where Power = Input power in horsepower
Torque = Input shaft torque in ft./lbs.
n = Speed in RPM

Example: A pump operating at 2400 RPM with a shaft torque of 70 ft. lbs. has input power of 32 HP

$$\text{Power} = \frac{(2400\text{RPM})(70 \text{ ft.lbs.})}{5252} = 32 \text{ HP}$$

VII. **Formula for calculation of volumetric efficiency**

$$\text{Volumetric Eff} = \frac{\text{Actual flow rate}}{\text{Theoretical flow rate}}$$

Example: The outlet flow rate of 2.56 in^3/rev. pump operating at 2400 rpm is measured to be 22.5 gallons per minute (GPM). The volumetric efficiency is 84.4%.

Theoretical flow rate =

$$\frac{n \times d}{231} = \frac{2400 \text{ RPM} \times 2.56\text{in}^3}{231}/\text{rev} = 26.6 \text{ GPM}$$

$$\text{Volumetric Eff} = \frac{22.5 \text{ GPM}}{26.6 \text{ GPM}} = 0.844$$

VIII. **Operation of a gear pump** (Transparency 1)

A. The gear pump consists of two or more gears

1. Drive gear — Power from engine or motor is applied to this gear

2. Driven gear — Rotation of driver gear also causes rotation of driven gear

B. As the gears pass the inlet of the pump, the space between the gear teeth fills with fluid

C. The rotation of the gears carries the fluid around the outside perimeter of the gears to the outlet

INFORMATION SHEET

IX. **Construction and operation of vane pumps** (Transparency 2)

A. Fixed displacement

1. A fixed displacement vane pump consists of a slotted rotor inside a circular chamber

2. The chamber has inlet and outlet ports for supplying low pressure fluid and expelling pressurized fluid

3. Vanes are installed into the slots in the rotor and are free to move in a radial direction (that is, towards or away from the center of the rotor)

4. As the rotor rotates, the vanes are forced outward to contact the surface of the circular chamber

5. The rotor is installed offset (not in the center) in the circular chamber

6. As the rotor rotates a vane past the inlet port, a volume of fluid is trapped between two vanes

7. Because the rotor is installed offset in the circular chamber, the volume contained between two rotors becomes smaller and the trapped fluid is expelled from the outlet

(NOTE: This is the operation of an unbalanced vane pump. A balanced vane pump is similar except it has two inlets and two outlets.)

B. Variable displacement — The displacement of a vane pump can be changed by changing the position of the rotor in the circular chamber

(NOTE: Only unbalanced vane pumps may be used as variable displacement pumps.)

X. **Types of piston pumps** (Transparency 3)

A. Axial — Pistons are parallel to the axis of the pump

B. Radial — Pistons are perpendicular to the axis of the pump

XI. **Operation of a radial piston pump** (Transparency 3)

A. Pistons are installed radially to the pump, or perpendicular to the shaft

B. The pistons are driven by a cam on the pump shaft

C. As the shaft rotates, the cam moves the pistons

D. On the downward stroke of each piston, a spring-loaded valve opens and fluid is drawn into the piston cylinder from the pump inlet

E. During the upward stroke the inlet valve is forced closed and another valve directs the oil to the outlet

INFORMATION SHEET

XII. **Types of axial piston pumps**

   A. In-line

   B. Bent-axis

XIII. **Construction and operation of axial piston pumps**

   A. In-line (Transparency 3)

      1. The pistons are installed in a circular cylinder block (Transparency 4)

      2. The cylinder block is attached to the pump shaft and rotates with the shaft

      3. The pistons extend out the cylinder block to contact a fixed plate, called the swash plate, which is installed at an angle and does not rotate

      4. As the pump shaft rotates, the cylinder block and pistons also turn

      5. Since the swash plate is fixed (does not rotate) the pistons are forced in and out of the cylinder (Transparency 4)

      6. The pump inlet and outlets are positioned so that fluid is drawn into the cylinder bore from the inlet when the piston is retracted and forced out the outlet when the piston is extended

      7. The port plate (also called valve plate) is a stationary plate which directs the flow in the correct direction

   B. Bent-axis (Transparency 5)

      1. The bent-axis pump consists of a drive member connected to the pump shaft

      2. The pistons are installed in a cylinder block

      3. The cylinder block is mounted at an angle to the pump shaft and drive member

      4. As the pump shaft turns, the drive member and cylinder block are also turned

      5. Since pistons are attached to the drive member, they are forced to reciprocate (move in and out) in the cylinder bore

      6. During the downward stroke (retracting) fluid is pulled into the cylinder bore from the inlet port

INFORMATION SHEET

7. During the upward stroke fluid is pushed out of the cylinder bore to the outlet port

XIV. **Operation of a variable displacement axial piston pump** (Transparency 6)

A. The displacement of an axial piston pump can be changed by changing the angle the swash plate makes with the pump shaft

B. The displacement is determined by the piston's travel into and out of the cylinder barrel

(NOTE: A small swash plate angle causes a small amount of piston travel and therefore small displacement. Similarly, a large angle causes large displacement.)

C. Varying the displacement is a common method of changing the flow rate of a pump when the pump speed (RPM) is fixed

D. Hand screws and hydraulic cylinders are two means of varying the swash plate angle

XV. **Parts of a servo-controlled variable displacement pump** (Transparency 7)

A. Tilting swash plate

B. Upper servo cylinder

C. Lower servo cylinder

(NOTE: The upper and lower servo cylinders are used to position the swash plate to the correct angle and hold it at that angle. Hydraulic cylinders are used because of the very large forces required to move and hold the swash plate.)

D. Control lever

(NOTE: The control lever is used to set a desired displacement.)

E. Displacement control valve

(NOTE: When the control lever is moved, the displacement control valve is opened to direct flow to the correct servo cylinder to move the swash plate. As the swash plate moves to the correct position, the linkage connecting the swash plate, control valve, and control lever tends to close the valve. When the swash plate reaches the correct position the valve closes to trap fluid in the two servo cylinders and hold the swash plate in the correct position. This servo system allows the large forces required for moving and holding the swash plate to be controlled by much smaller forces at the control lever.)

INFORMATION SHEET

F. Charge pump

(NOTE: Most piston pumps require a charge pump on the inlet. This insures that the cylinders fill with oil and that the pistons maintain contact with the swash plate at all times. Servo-controlled variable displacement pumps also use this for force (pressure) for the servo system. The charge pump is usually a gear pump which supplies the fluid at the inlet of the piston pump in the range of 25 to 150 PSI. The charge pump may be physically a part of the piston pump or may be externally mounted.)

XVI. **Components and functions of pressure compensated axial piston pumps** (Transparency 8)

(NOTE: Many hydraulic systems are designed to operate with a constant pressure at the outlet of the pump. Because the amount of flow required from the pump by the rest of the system may change, the displacement of the pump must be changed. A pump which will automatically change its displacement (in order to keep a constant pressure) is known as a pressure compensated pump.)

A. Swash plate — Varies the displacement of the pump

(NOTE: The term yoke is often used instead of swash plate. Although yoke is a more common term when discussing pressure compensated pumps, either is acceptable.)

B. Swash plate (yoke) return cylinder — Normally holds the pump at full displacement

C. Servo cylinder — Moves and holds the swash plate

D. Compensator adjustment spring — Used to set the compensator pressure, that is, the pressure at the pump outlet

E. Compensator (servo) valve — Controls the flow of oil to the servo cylinder

(NOTE: When the force on the servo valve created by the outlet pressure is exactly balanced by the compensator spring, fluid flow to the servo cylinder is blocked. When the outlet pressure is too low, the valve shifts to allow the fluid in the cylinder to be released to the pump case thus causing the pump displacement to increase. When the outlet pressure is too high, the valve shifts the other direction to allow the fluid from the outlet to flow into the servo cylinder and decrease the displacement.)

F. Drain to case — Drains fluid from the servo cylinder to the pump case

(NOTE: In addition, continuous flow from the pump outlet is maintained through the case. This provides cooling flow for the pump.)

G. Load pressure (outlet pressure) — Used to shift the compensator valve

INFORMATION SHEET

XVII. **Causes of hydraulic pump cavitation**

(NOTE: Cavitation occurs when there is not ample fluid to fill the pumps inlet and air bubbles form. When these bubbles collapse, a small implosion (inward explosion) occurs which tends to erode and destroy the pump's internal surfaces.)

A. Restriction in the pump inlet line

(NOTE: A restriction in the inlet line can cause a drop in the pressure at the pump inlet. This low pressure allows the formation of the air bubbles and thus cavitation.)

B. Replacing pump inlet lines with lines which are too small

(NOTE: Lines too small can also cause low pressure at the pump inlet.)

C. Placing reservoir too far from pump

(NOTE: Long lines to the pump can cause low inlet pressure.)

D. Low fluid level in reservoir

(NOTE: Low fluid level can cause the pump to "starve.")

XVIII. **Common causes of hydraulic pump failure**

A. Contaminated fluid

(NOTE: This is one of the most common causes of pump failure. Contamination includes not only solid particles, but also other contaminants such as water and air.)

B. Improper fluid

(NOTE: The incorrect fluid may result in pump failure in a very short time. The fluid must have the correct viscosity properties, temperature range, and additives.)

C. Improper operating procedures

(NOTE: Continuous operation at the pump's maximum limits or exceeding its limits can greatly reduce the pump life. For example, excessive pump pressure or speed can vastly reduce the life of tne bearings.)

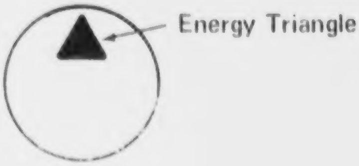
D. Cavitation

E. Improper pump maintenance

INFORMATION SHEET

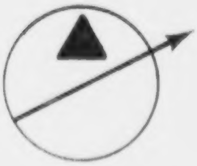
XIX. Symbols for types of pumps

A. Fixed displacement

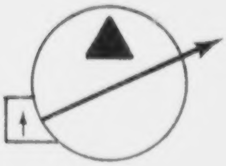


(NOTE: The fluid flow is in the direction of the energy triangle.)

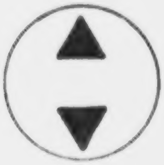
B. Variable displacement



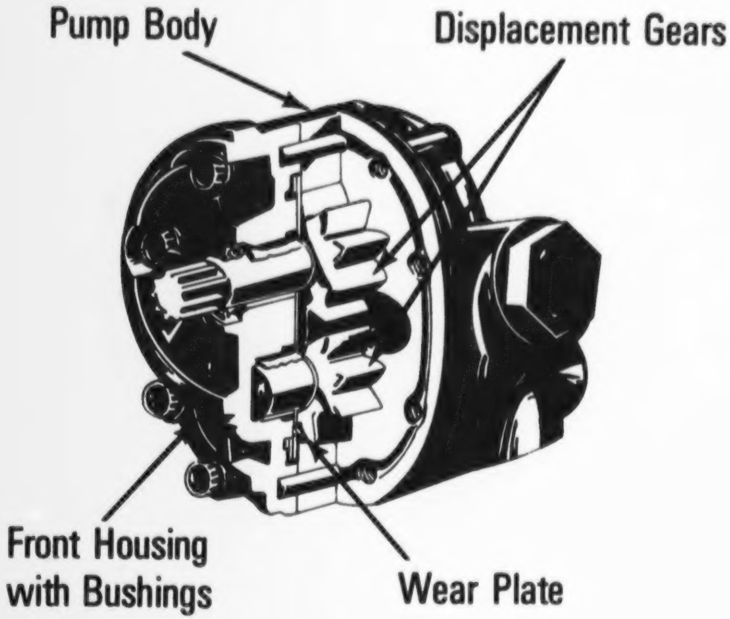
C. Pressure compensated



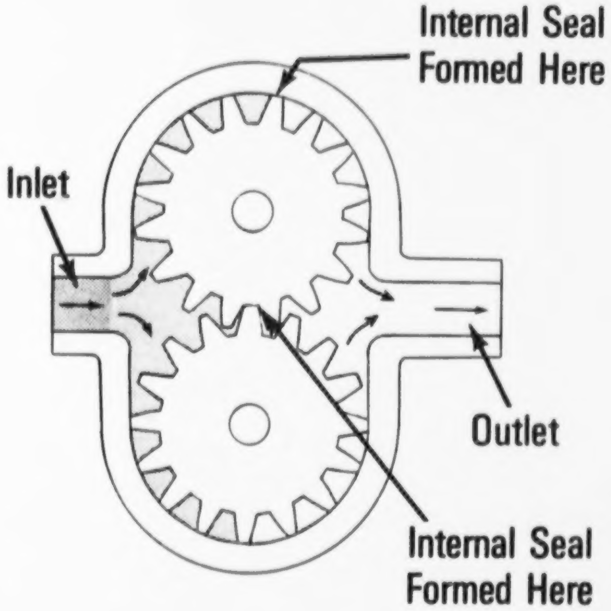
D. Bi-directional



Gear Pump

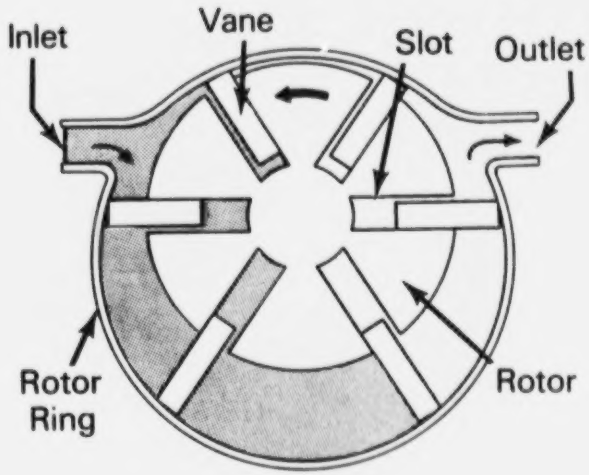

Pump Body
Displacement Gears
Front Housing with Bushings
Wear Plate

Gear Pump

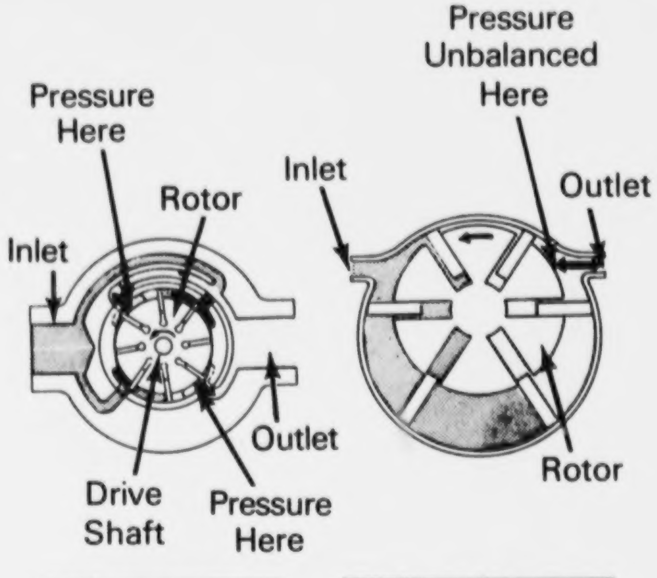

Internal Seal Formed Here
Inlet
Outlet
Internal Seal Formed Here

Operation of Gear Pump

Vane Pumps


Inlet
Vane
Slot
Outlet
Rotor Ring
Rotor

Unbalanced Vane Pump
in Operation

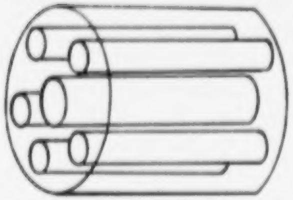

Pressure Here
Rotor
Inlet
Outlet
Drive Shaft
Pressure Here
Pressure Unbalanced Here
Inlet
Outlet
Rotor

Balanced Vane

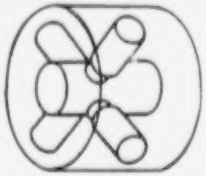
Unbalanced Vane

Balanced vs. Unbalanced Vane Pumps --
Pressure on Rotor and Shaft

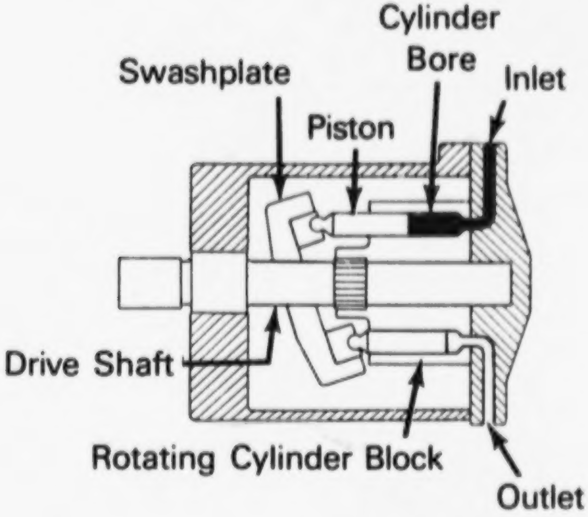
Types of Piston Pumps



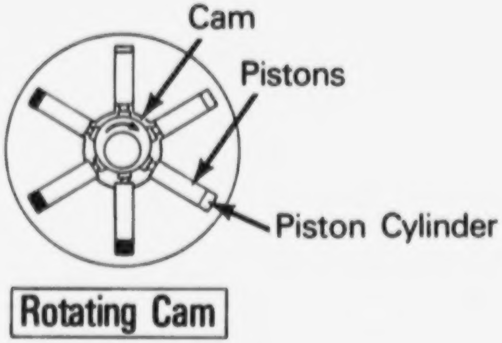
Axial Piston Pump



Radial Piston Pump

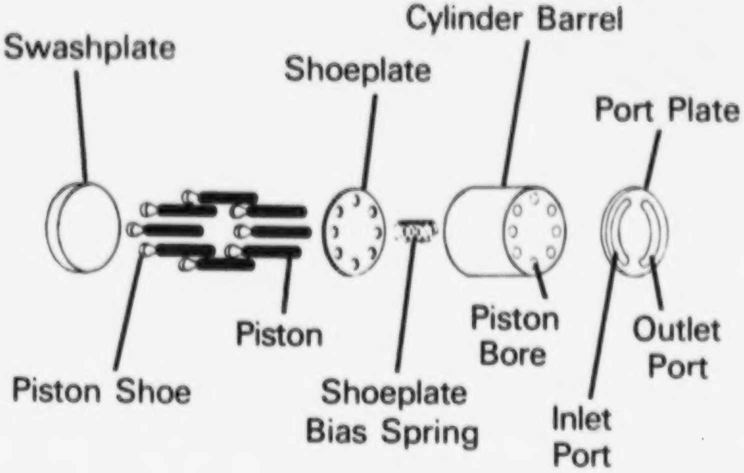

Cylinder Bore
Swashplate
Inlet
Piston
Drive Shaft
Rotating Cylinder Block
Outlet

Operation of an In-line Axial Piston Pump

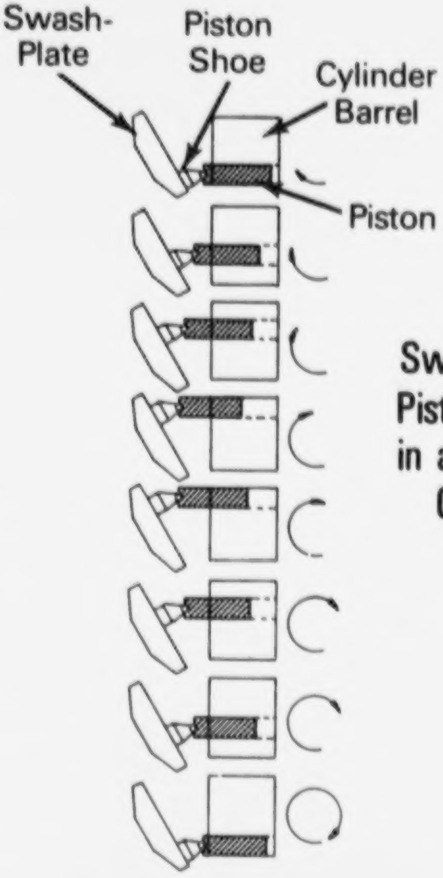

Cam
Pistons
Piston Cylinder
Rotating Cam

Operation of Radial Piston Pump

Construction and Operation of Axial Piston Pumps

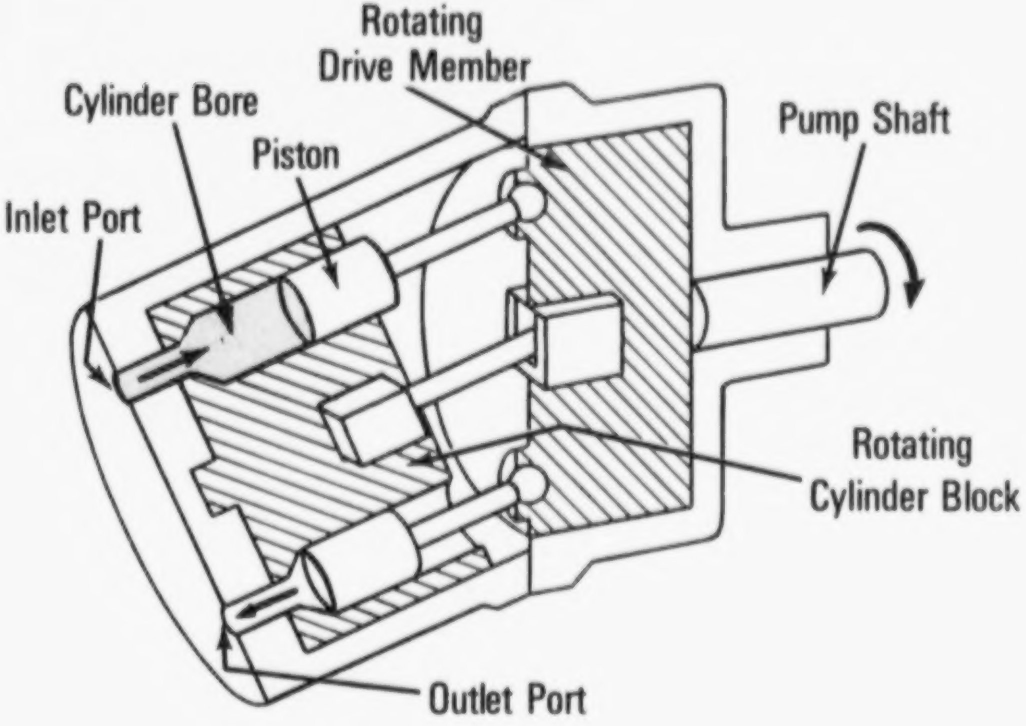

Swashplate
Shoeplate
Cylinder Barrel
Port Plate
Piston Shoe
Piston
Shoeplate Bias Spring
Piston Bore
Inlet Port
Outlet Port

Piston Installation in Circular Cylinder Block

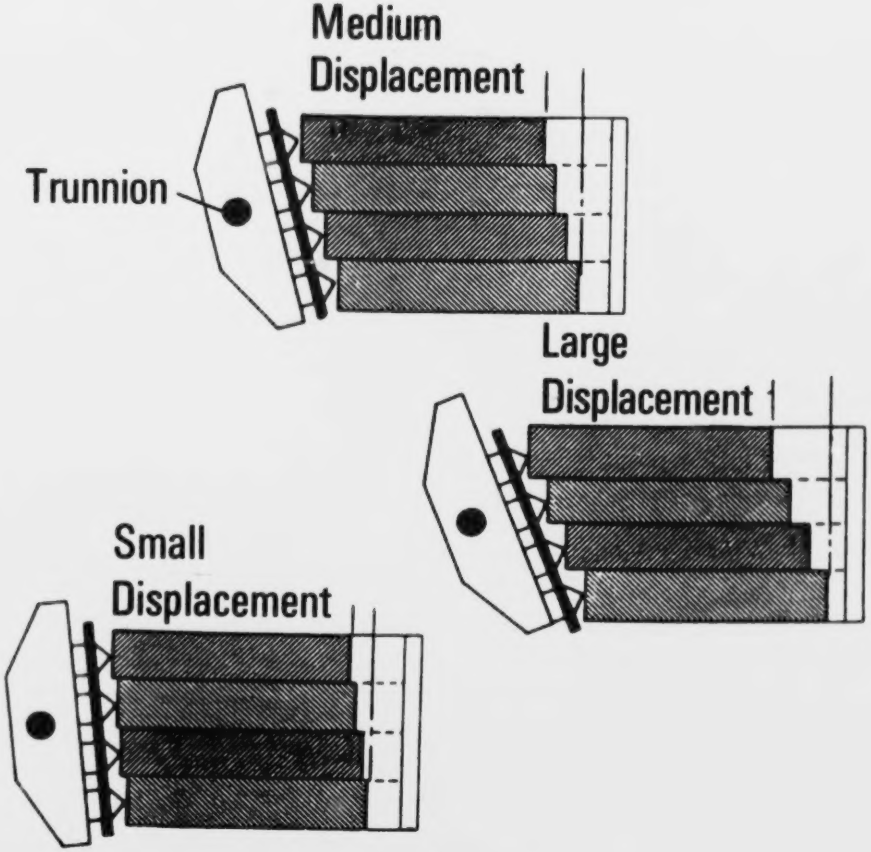

Swash-Plate
Piston Shoe
Cylinder Barrel
Piston

Swash-Plate Piston Forced in and out of Cylinder

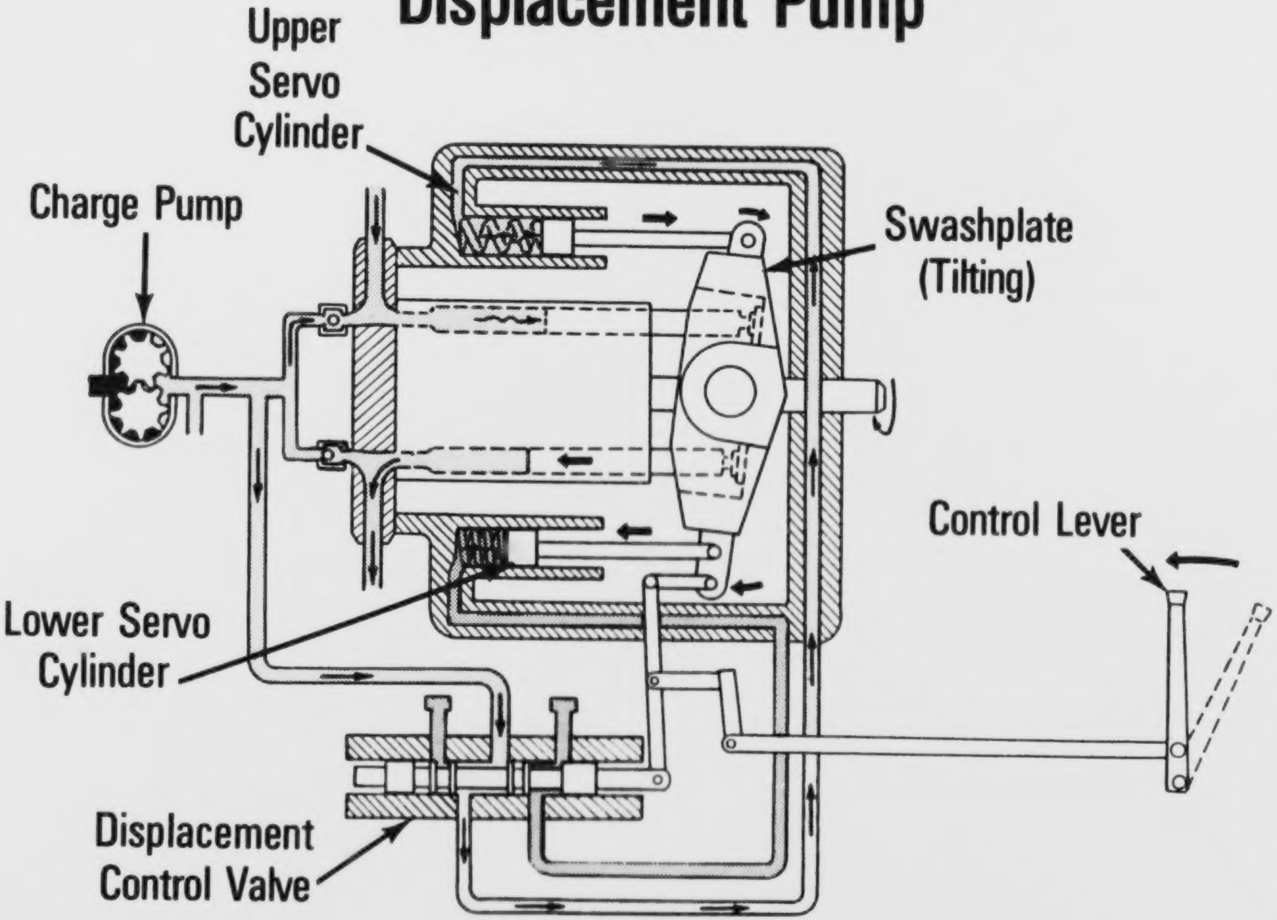
Bent-Axis Axial Piston Pump — Fixed Displacement


Rotating Drive Member
Cylinder Bore
Piston
Inlet Port
Pump Shaft
Rotating Cylinder Block
Outlet Port

Operation of Variable Displacement Axial Piston Pump


Medium Displacement
Trunnion
Large Displacement
Small Displacement

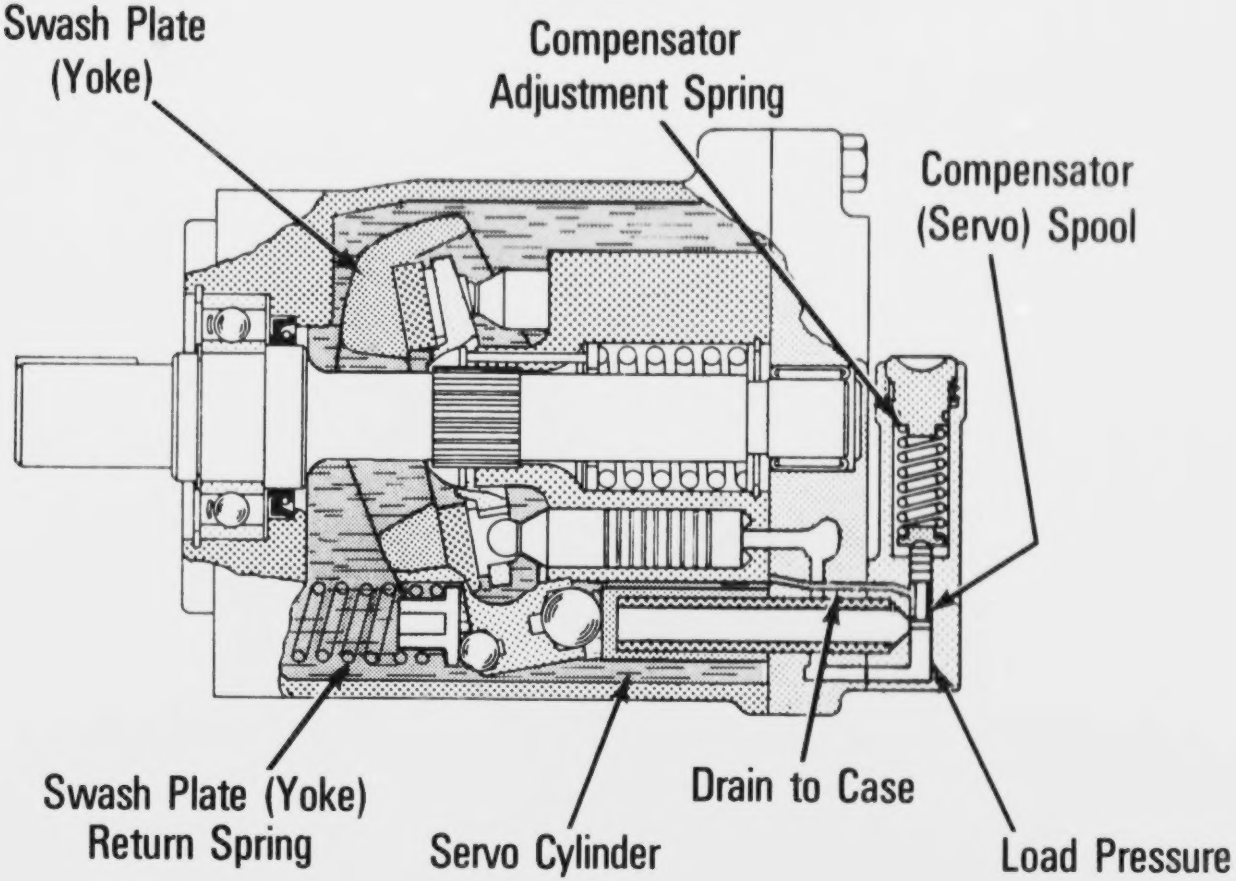
Parts of a Servo-Controlled Variable Displacement Pump


Upper Servo Cylinder
Charge Pump
Swashplate (Tilting)
Control Lever
Lower Servo Cylinder
Displacement Control Valve

150

151

Operation of Pressure Compensated Axial Piston Pumps


Swash Plate (Yoke)
Compensator Adjustment Spring
Compensator (Servo) Spool
Swash Plate (Yoke) Return Spring
Servo Cylinder
Drain to Case
Load Pressure

PUMPS
UNIT VII

ASSIGNMENT SHEET #1 — CALCULATE PUMP DISPLACEMENT, FLOW RATE, INPUT AND OUTPUT POWER, AND OVERALL EFFICIENCY

Directions: Solve the following problems using the formula which applies to that problem.

$$\text{Pump displacement} = d = \frac{231\ Q}{n}$$

$$\text{Pump flow rate} = Q = \frac{n \times d}{231}$$

$$\text{Pump output power} = HP = \frac{P \times Q}{1714}$$

$$\text{Pump input power} = HP = \frac{n \times \text{Torque}}{5252}$$

$$\text{Pump overall efficiency} = \frac{\text{Output power}}{\text{Input power}}$$

A. What is the pump displacement when the flow rate is 23 GPM at 1900 RPM?

B. What is the flow rate of a 3.0 in^3/rev. pump operating at 2600 RPM?

C. What is the output power of a pump with 21 GPM flow and 3200 PSI outlet pressure?

D. What is the input power of a pump operating at 2500 RPM with a shaft torque of 70 ft. lbs.?

E. What is the overall efficiency of a pump if the output power is 40 HP and the input power is 46 HP?

F. What is the flow rate of a 3.12 in^3/rev. pump operating at 2200 RPM?

ASSIGNMENT SHEET #1

G. What is the input power of a pump operating at 3000 RPM with a shaft torque of 75 ft. lbs.?

____

H. What is the pump displacement if the outlet flow is 26 GPM at 2000 RPM?

____

I. What is the output power of a pump with a 25 GPM flow and 3000 PSI pressure?

____

PUMPS
UNIT VII

ANSWERS TO ASSIGNMENT SHEET

A. 2.80 in^3/rev.
B. 34 GPM
C. 39 HP
D. 33 HP
E. 87%
F. 29.7 GPM
G. 43 HP
H. 3 in^3/rev.
I. 44 HP

PUMPS
UNIT VII

JOB SHEET #1 — DISASSEMBLE, INSPECT, AND REASSEMBLE A GEAR PUMP

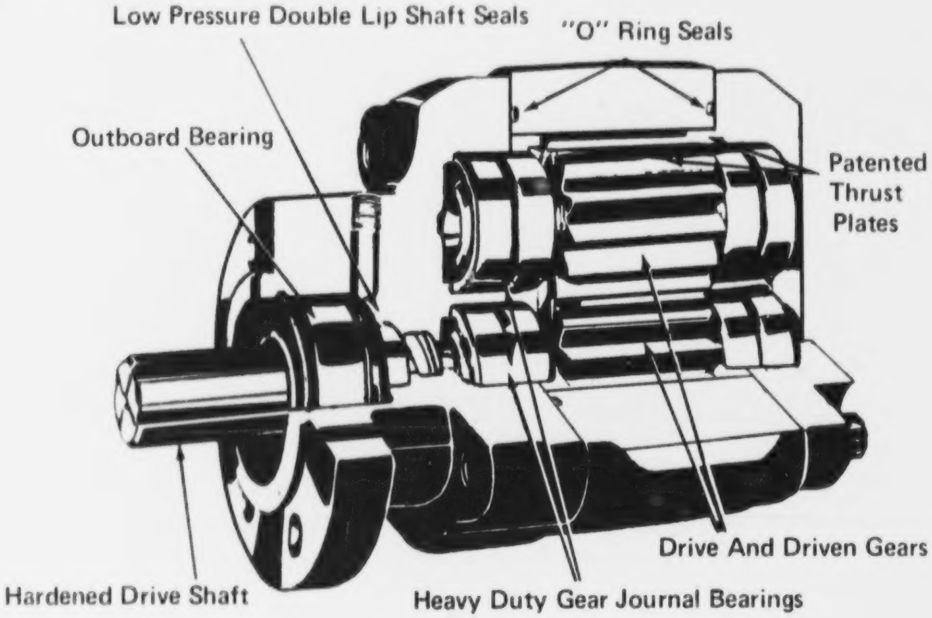
A. Tools and materials

1. Gear pump
2. Service manual for pump (if available)
3. Hand tool set
4. Solvent
5. Lint free shop towels
6. Safety glasses

B. Routine #1 — Disassemble the pump

(NOTE: Figure 1 shows a cut-away drawing of a typical gear pump with an outboard bearing on the pump shaft. Figure 2 is an exploded view of this pump.)

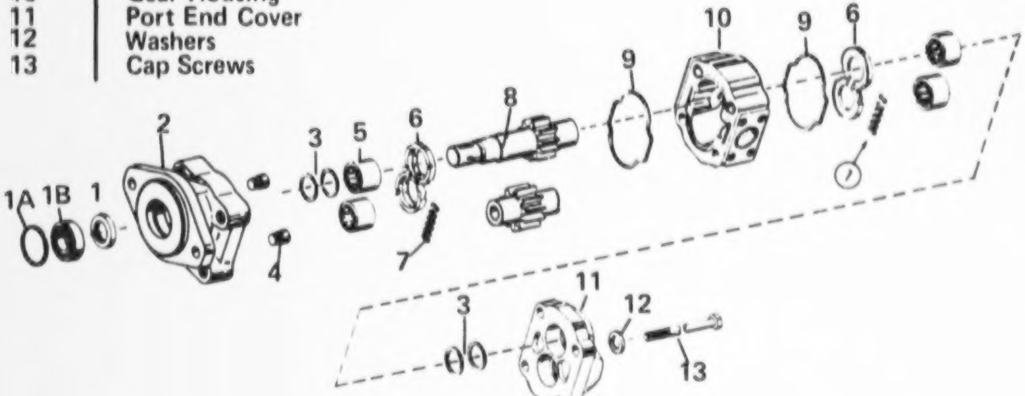
FIGURE 1


Low Pressure Double Lip Shaft Seals
"O" Ring Seals
Outboard Bearing
Patented Thrust Plates
Drive And Driven Gears
Hardened Drive Shaft
Heavy Duty Gear Journal Bearings

JOB SHEET #1

FIGURE 2

Item	Description
1A	Snap Ring
1B	Outboard Bearing
1	Double Lip Seal
2	Shaft End Cover
3	Shaft Seals
4	Check Assemblies
5	Roller Bearings
6	Thrust Plates
7	Pocket Seals
8	Integral Shaft and Gear Set
9	Gasket Seals
10	Gear Housing
11	Port End Cover
12	Washers
13	Cap Screws



1. Thoroughly clean the external surfaces of the pump with solvent
2. Dry the pump with shop towels
3. Place the pump on a clean surface for disassembly
4. Remove the clip ring retainer on the outboard shaft bearing (if used)
5. Remove the bearing
6. Remove the four cap screws which hold the pump housing together
7. Slowly remove the port (rear) end cover from the pump
8. Remove the two port side roller bearings from the assembly
9. Remove the rear thrust plate

   (NOTE: Note the orientation of the plate.)
10. Remove the gear housing from the pump

JOB SHEET #1

11. Carefully remove the two gears from the pump

12. Remove the shaft side thrust plate noting orientation

13. Remove the two shaft side roller bearings

14. Remove shaft seal

☐ Have your instructor check your work

C. Routine #2 — Inspect the pump

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Examine the two thrust plates for excessive wear or scoring		
2. Examine the gears for excessive wear and broken teeth		
3. Examine the roller bearings for excessive wear and fractured bearings		
4. Examine the shaft seal for scoring		
5. Examine the gear housing seals (usually O-rings) for nicks or breaks		
6. Replace any part found to be defective		

☐ Have your instructor check your work

D. Routine #3 — Reassemble the pump

(NOTE: Pre-lube parts during assembly.)

1. Carefully install the shaft seal

2. Install the two shaft side roller bearings

3. Install the shaft side thrust plate

4. Install the two gears into the shaft end cover

JOB SHEET #1

5. Insure that the two seals on the gear housing are properly installed and then lower the gear housing around the two gears and align with the shaft end cover

6. Install the port side thrust plate

7. Install the port side roller bearings

8. Install the port side end cover onto the assembly and carefully align

9. Install the four cap screws

10. Uniformly torque the screws by alternately applying torque to screws on opposite sides of the pump

11. Reinstall the shaft outboard bearing and clip ring

12. Fill pump with fluid as necessary before operation

☐ Have your instructor check your work

13. Clean up area and return tools and materials to proper storage

PUMPS
UNIT VII

JOB SHEET #2 — DISASSEMBLE, INSPECT, AND REASSEMBLE A PRESSURE COMPENSATED VARIABLE DISPLACEMENT PUMP

A. Tools and materials

1. Pressure compensated pump

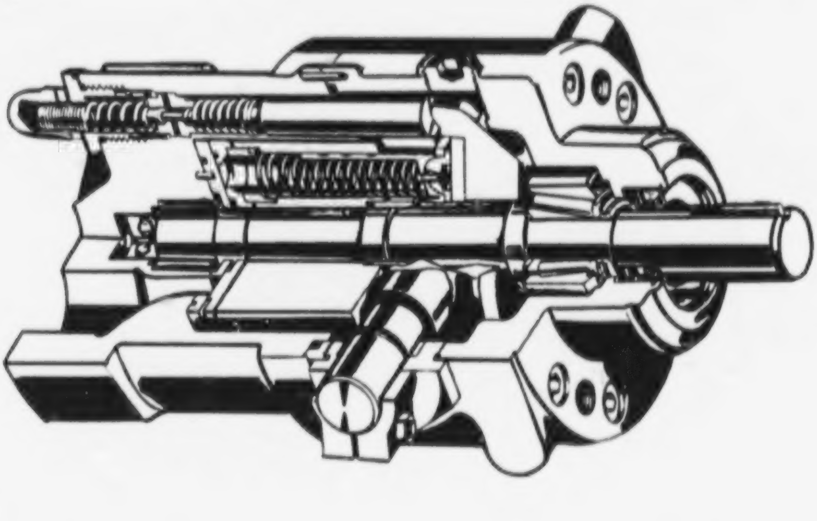
   (NOTE: This job sheet assumes that an in-line axial piston pump will be used. The procedures are similar for other types of pressure compensated pumps.)

2. Service manual for pump
3. Hand tool set
4. Solvent
5. Lint free shop towels
6. Safety glasses

B. Routine #1 — Disassemble the pump

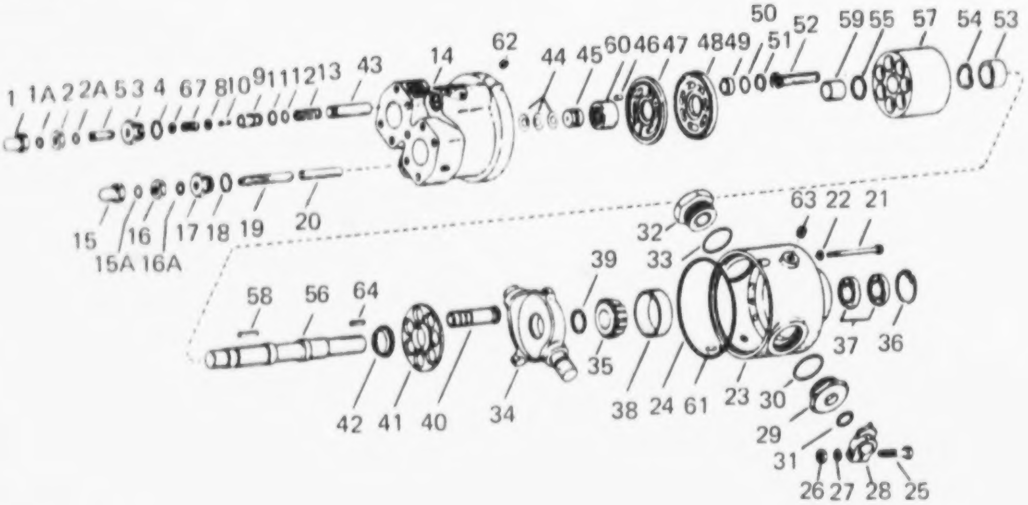
(NOTE: The procedures here assume a pressure compensated in-line axial piston pump. A cut-away view of such a pump is shown in Figure 1. An exploded view of this pump is shown in Figure 2.)

FIGURE 1



JOB SHEET #2

FIGURE 2

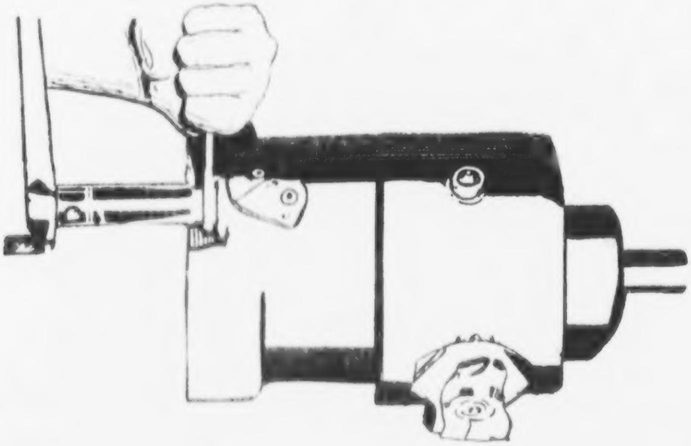

1
1A
2
2A
5
3
4
6
7
8
10
9
11
12
13
43
14
62
44
45
60
46
47
48
49
50
51
52
59
55
57
54
53
15
16
17
18
19
20
15A
16A
63
22
21
32
33
39
58
56
64
37
36
35
42
41
40
34
38
24
61
23
30
29
31
26
27
28
25

No.	Description	Qty.	No.	Description	Qty.	No.	Description	Qty.
1	Acorn nut	1				42	Ball bushing	1
1A	Packing, preformed	1	20	Control piston	1	43	Port end cover	1
2	Jam nut	1	21	Cap screw	8	44	Spring	3
2A	Packing, preformed	1	22	Washer	8	45	Bearing	1
3	Adjustment plug	1	23	Drive cover	1	46	Dowel	1
4	Preformed packing	1	24	Preformed packing	1	47	Fixed port plate	1
5	Adjustment screw	1	25	Cap screw	1	48	Rotating port plate	1
6	Spring seat	1	26	Nut	1	49	Cylinder seal	7
7	Compensator spring	1	27	Lockwasher	1	50	Preformed packing	7
8	Spring seat	1	28	Indicator	1	51	Washer	7
9	Compensator shell	1	29	Thru trunnion nut	1	52	Spring	7
10	Compensator piston	1	30	Preformed packing	1	53	Spring sleeve	1
11	Quad ring	1	31	Preformed packing	1	54	Wave washer	3
12	Quad ring	1	32	Blind trunnion nut	1	55	Snapring	1
13	Starting spring	1	33	Preformed packing	1	56	Drive shaft	1
14	Control piston	1	34	Reaction swivel assy	1	57	Rotor	1
15	Acorn nut	1	35	Bearing	1	58	Key	1
15A	Packing, preformed	1	36	Snapring	1	59	Bearing race	1
16	Jam nut	1	37	Seal	2	60	Bearing	1
16A	Packing, preformed	1	38	Bearing cup	1	61	Case dowel	1
17	Adjustment plug	1	39	Thrust washer	1	62	Pipe plug	1
18	Preformed packing	1	40	Piston assembly	7	63	Pipe plug	1
19	Adjustment screw	1	41	Holddown plate	1	64	Key	1

JOB SHEET #2

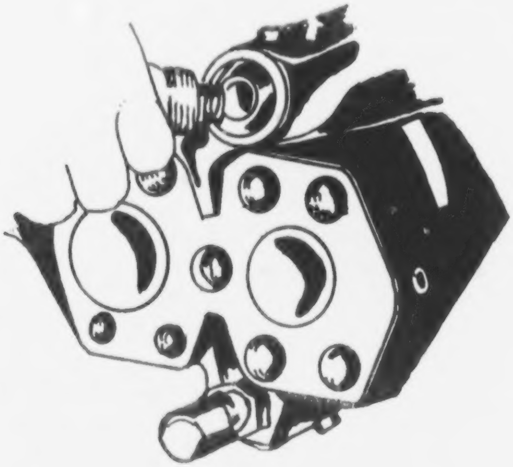
1. Clean the external surfaces of the pump using solvent to remove all dirt and grime
2. Dry pump with shop towels
3. Loosen the jam nut and unscrew the compensator adjustment screw (Figure 3)

FIGURE 3



4. Remove the compensator spring seat and compensator spring (Figure 4)

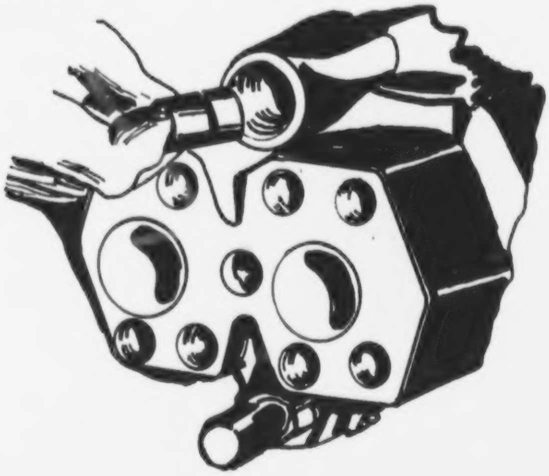
FIGURE 4



JOB SHEET #2

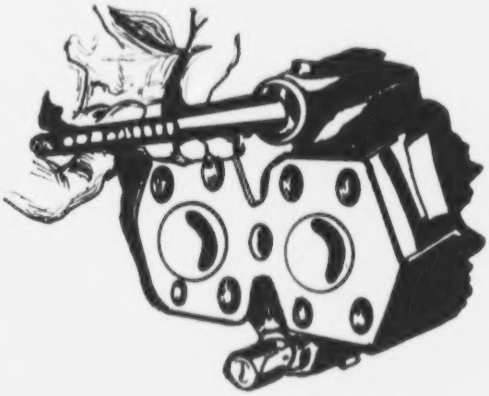
5. Remove the compensator spool (Figure 5)

FIGURE 5



6. Remove the compensator piston and spring (Figure 6)

FIGURE 6



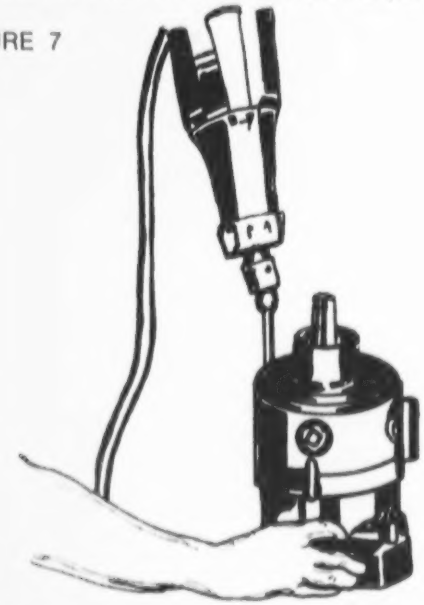
7. Remove the retaining nut for the compensator piston on the other side of the pump

8. Remove the spring and piston

JOB SHEET #2

9. Unscrew the cap screws that hold the pump housing together (Figure 7)

FIGURE 7



(NOTE: Be careful to lift the cover straight up. Be especially careful to insure that the pistons are free of the swash plate as shown in Figure 8.)

10. Carefully remove the drive end cover from the port end cover (Figure 9)

FIGURE 8

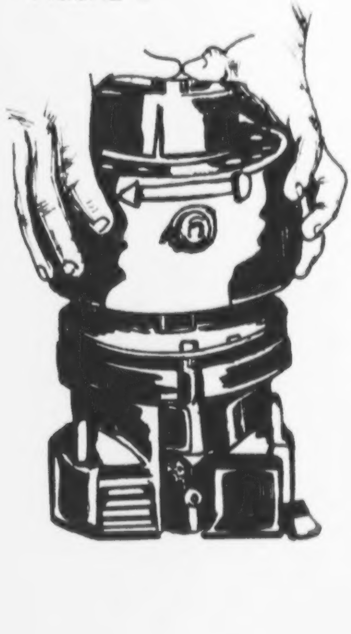
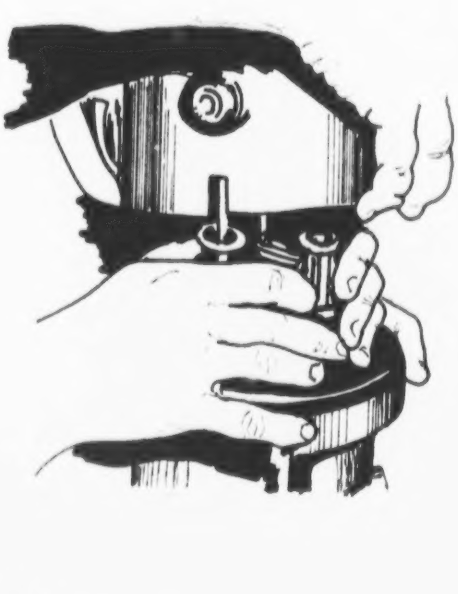


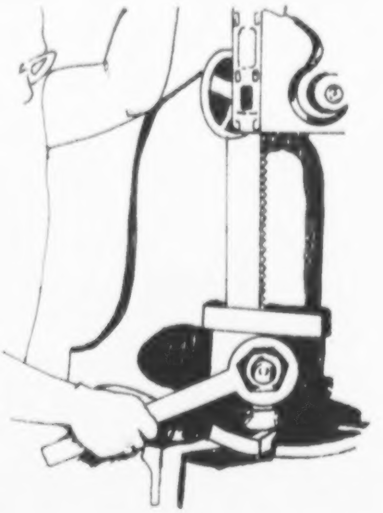
FIGURE 9



JOB SHEET #2

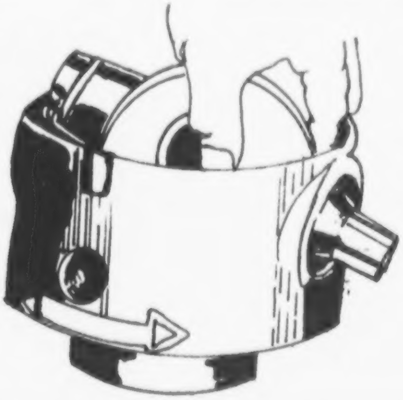
11. Remove the trunnion nut from the assembly (Figure 10)

FIGURE 10



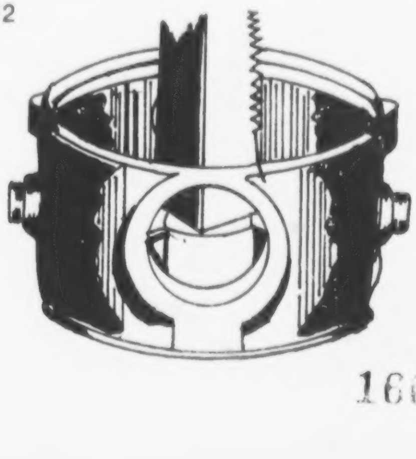
12. Remove the swash plate from the drive cover (Figure 11)

FIGURE 11



13. Remove the snap ring, seals and bearings from the shaft cover (Figure 12)

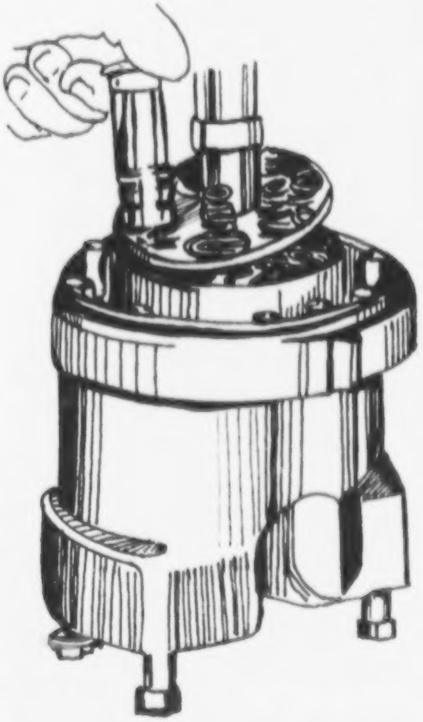
FIGURE 12



JOB SHEET #2

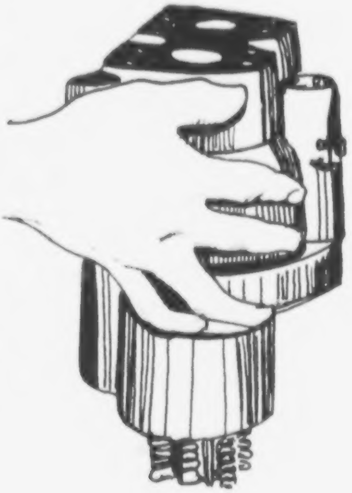
14. Remove the pistons from the assembly (Figure 13)

FIGURE 13



15. Remove the port end cover from the barrel and shaft assembly (Figure 14)

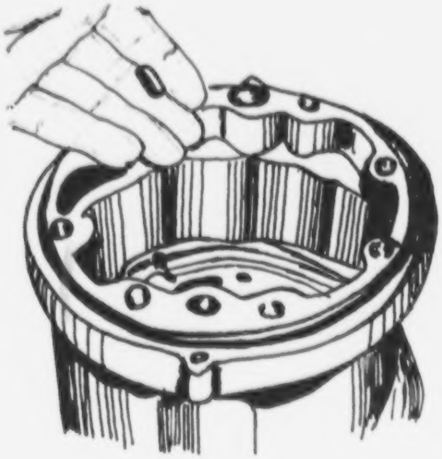
FIGURE 14



JOB SHEET #2

16. Remove the port plate from the port end cover (Figure 15)

FIGURE 15



☐ Have your instructor check your work

C. Routine #2 — Inspect the pump

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Inspect the pistons and piston bore for scoring or excessive wear		
2. Inspect the piston shoe for excessive wear		
3. Examine the swash plate for excessive wear		
4. Inspect the shaft seat for scoring and excessive wear		
5. Examine the compensator piston		
6. Examine the compensator piston		
7. Inspect the compensator fluid passages for blockage and clean if necessary		
8. Examine the port plate for wear or cracking		

☐ Have your instructor check your work

JOB SHEET #2

D. Routine #3 — Reassemble the pump

1. Install the port plate into the port end housing
2. Place the cylinder barrel and shaft assembly into the port end housing
3. Install the pistons into the assembly
4. Install the bearing, seal and seal-retainer ring into the shaft end cover
5. Install the swash plate into the shaft end cover
6. Install the trunnion nut to secure the swash plate
7. Make sure the port end cover is lying on a flat surface with the ports down, and carefully lower the shaft end cover onto the assembly
8. Make sure that the piston shoes properly contact the swash plate
9. Install the cap screws to secure the two halves of the pump assembly
10. Torque the screws to manufacturer's recommended specifications by tightening screws on opposite sides of the pump in sequence
11. Install the lower piston with spring and tighten screw cap
12. Install the upper piston with spring, compensator spool, spool spring, and adjustment screw
13. Tighten adjustment screw only partially into the pump

☐ Have your instructor check your work

14. Clean up area and return tools and materials to proper storage

PUMPS
UNIT VII

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. A device which creates the flow of fluid

_____b. The volume of fluid which is transferred from the pump inlet to the outlet during one revolution of the pump

_____c. The actual flow rate from a pump divided by the theoretical flow rate

_____d. The formation of air bubbles in the inlet of a pump because the inlet does not completely fill with fluid

_____e. Air in the fluid

_____f. Pressure in the return line caused by flow through the line from the pump to the reservoir

1. Displacement
2. Back pressure
3. Pump
4. Volumetric efficiency
5. Cavitation
6. Aeration

2. Distinguish between positive and nonpositive displacement pumps by placing an "X" next to the description of positive displacement pumps.

_____a. A pump whose inlet and outlet are hydraulically connected so that fluid can recirculate in the pump when pressure builds up

_____b. A pump whose inlet is sealed from the outlet; will deliver fluid any time the inlet is kept supplied and the pump is driven

3. Name three kinds of positive displacement pumps.

a. ____________________

b. ____________________

c. ____________________

4. Calculate the pump displacement for a pump which has an outlet of 30 GPM at 200 RPM, using the formula for displacement, $d = \frac{231\,Q}{n}$

TEST

5. Calculate the flow rate for a 2.88 in^3/rev. pump operating at 2000 RPM using the formula for flow rate, $Q = \frac{n \times d}{231}$

6. a. Calculate the output power for a pump operating with 18 GPM flow and 2700 PSI outlet pressure using the formula, $\text{Power} = \frac{P \times Q}{1714}$

   b. Calculate the input power for a pump operating at 2000 RPM with a shaft torque of 50 ft. lbs. using the formula, $\text{Power} = \frac{n \times \text{Torque}}{5252}$

7. Calculate the volumetric efficiency of a 2.56 in^3/rev. pump operating at 2300 RPM with an outlet flow rate of 22 gallons per minute (GPM).

TEST

8. Discuss the operation of a gear pump.

____

____

____

____

____

____

9. Select true statements concerning the operation of vane pumps by placing an "X" next to the statements which are true.

______a. A fixed displacement vane pump consists of a slotted rotor inside a circular chamber

______b. In a fixed displacement pump, vanes are installed into the slots in the rotor and are free to move in an axial direction

______c. As the rotor rotates in a fixed displacement pump, the vanes are forced outward to contact the surface of the circular chamber

______d. In a fixed displacement pump, as the rotor rotates a vane past the inlet port, a volume of fluid is trapped between two vanes

______e. Because the rotor is installed offset in the circular chamber in the fixed displacement pump, the volume contained between two rotors becomes smaller and the trapped fluid is expelled from the outlet

______f. The trapped fluid is expelled from the outlet of the pump and is at a lesser pressure than the inlet

______g. In a variable displacement pump, the displacement vane can be changed by changing the position of the rotor in the circular chamber

10. Distinguish between axial and radial piston pumps by placing an "X" next to the description of an axial piston pump.

______a. Pistons are parallel to the axis of the pump

______b. Pistons are perpendicular to the axis of the pump

TEST

11. Select true statements concerning the operation of a radial piston pump by placing an "X" next to the statements which are true.

_____a. Pistons are installed radially to the pump

_____b. The pistons are driven by a cam on the pump shaft

_____c. As the shaft rotates, the pistons move the cam

_____d. On the downward stroke of each piston, a spring-loaded valve opens and fluid is drawn into the piston cylinder from the pump inlet

_____e. During the upward stroke the inlet valve is forced closed and another valve directs the oil to the outlet

12. Name two types of axial piston pumps.

a. ____

b. ____

13. Discuss the construction and operation of axial piston pumps.

a. In-line

____

____

____

____

____

____

____

____

____

____

____

____

TEST

b. Bent-axis

14. Select true statements concerning the operation of a variable displacement axial piston pump by placing an "X" next to the statements which are true.

______a. The displacement of an axial piston pump can be changed by changing the angle the rotor makes with the pump shaft

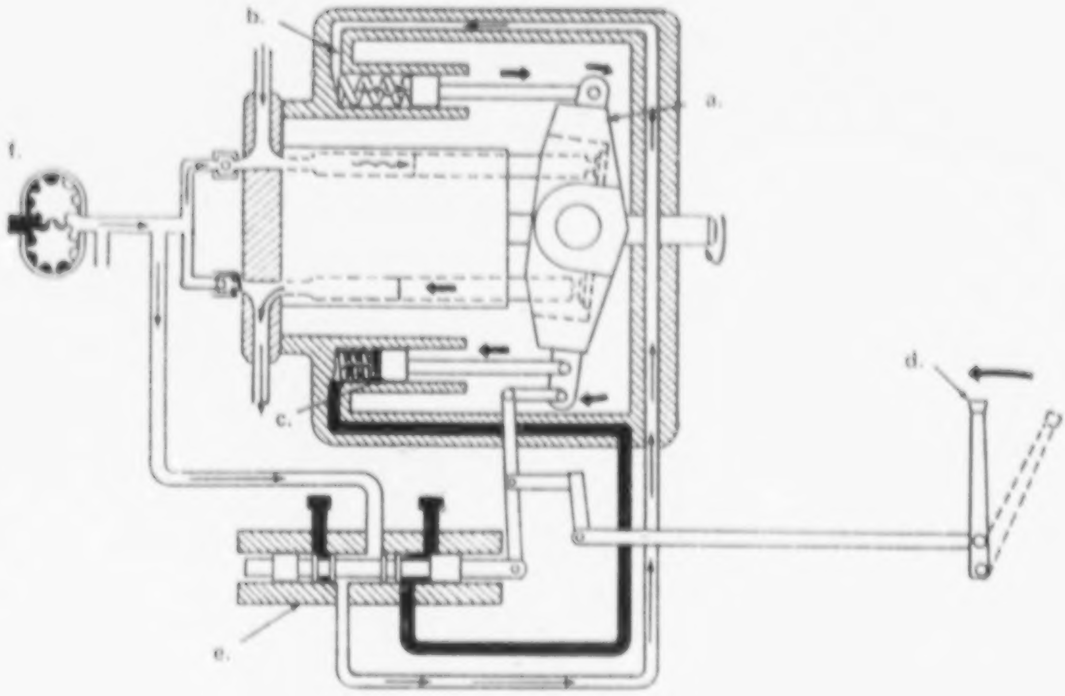
______b. The displacement is determined by the piston's travel into and out of the cylinder barrel

______c. Varying the displacement is a common method of changing the flow rate of a pump when the pump speed is fixed

______d. Hand screws and hydraulic cylinders are two means of varying the swash plate angle

TEST

15. Identify the parts of a servo-controlled variable displacement pump.



a. ______________________

b. ______________________

c. ______________________

d. ______________________

e. ______________________

f. ______________________

TEST

16. Match the components of the pressure compensated axial piston pumps on the right with the correct functions.

______a. Varies the displacement of the pump

______b. Normally holds the pump at full displacement

______c. Moves and holds the swash plate

______d. Used to set the compensator pressure, that is, the pressure at the pump outlet

______e. Controls the flow of oil to the servo cylinder

______f. Drains fluid from the servo cylinder to the pump case

______g. Used to shift the compensator valve

1. Load pressure
2. Swash plate return cylinder
3. Compensator adjustment spring
4. Drain to case
5. Swash plate
6. Servo cylinder
7. Compensator valve

17. List four causes of hydraulic pump cavitation.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

18. List four common causes of hydraulic pump failure.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

19. Draw the symbols for the following pumps.

a. Fixed displacement

TEST

b. Variable displacement

c. Pressure compensated

d. Bi-directional

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

20. Demonstrate the ability to:

    a. Disassemble, inspect, and reassemble a gear pump.

    b. Disassemble, inspect, and reassemble a pressure compensated variable displacement pump.

PUMPS
UNIT VII

ANSWERS TO TEST

1. a. 3
   b. 1
   c. 4
   d. 5
   e. 6
   f. 2

2. b

3. Any three of the following:
   a. Gear
   b. Vane
   c. Piston
   d. Screw

4. 3.465 in^3/rev.

5. 24.9 GPM

6. a. 28 HP
   b. 19 HP

7. 86%

8. Discussion should include:
   a. The gear pump consists of two or more gears
      1) Drive gear — Power from engine or motor is applied to this gear
      2) Driven gear — Rotation of driver gear also causes rotation of driven gear
   b. As the gears pass the inlet of the pump, the space between the gear teeth fills with fluid
   c. The rotation of the gears carries the fluid around the outside perimeter of the gears to the outlet

9. a, c, d, e, g

10. a

11. a, b, d, e

12. a. In-line
    b. Bent-axis

13. Discussion should include:
    a. In-line
       1) The pistons are installed in a circular cylinder block
       2) The cylinder block is attached to the pump shaft and rotates with the shaft
       3) The pistons extend out the cylinder block to contact a fixed plate, called the swash plate, which is installed at an angle and does not rotate
       4) As the pump shaft rotates, the cylinder block and pistons also turn

ANSWERS TO TEST

    5) Since the swash plate is fixed the pistons are forced in and out of the cylinder
    6) The pump inlet and outlets are positioned so that fluid is drawn into the cylinder bore from the inlet when the piston is retracted and forced out the outlet when the piston is extended
    7) The port plate is a stationary plate which directs the flow in the correct direction
  b. Bent-axis
    1) The bent axis consists of a drive member connected to the pump shaft
    2) The pistons are installed in a cylinder block
    3) The cylinder block is mounted at an angle to the pump shaft and drive member
    4) As the pump shaft turns, the drive member and cylinder block are also turned
    5) Since pistons are attached to the drive member, they are forced to reciprocate in the cylinder bore
    6) During the downward stroke fluid is pulled into the cylinder bore from the inlet port
    7) During the upward stroke fluid is pushed out of the cylinder bore to the outlet port

14. b, c, d

15. a. Tilting swash plate
  b. Upper servo cylinder
  c. Lower servo cylinder
  d. Control lever
  e. Displacement control valve
  f. Charge pump

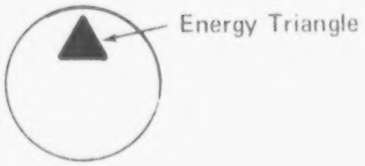
16. a. 5
  b. 2
  c. 6
  d. 3
  e. 7
  f. 4
  g. 1

17. a. Restriction in the pump inlet line
  b. Replacing pump inlet lines with lines which are too small
  c. Placing reservoir too far from pump
  d. Low fluid level in the reservoir

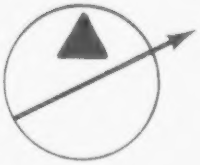
18. Any four of the following:
  a. Contaminated fluid
  b. Improper fluid
  c. Improper operating procedures
  d. Cavitation
  e. Improper pump maintenance

ANSWERS TO TEST

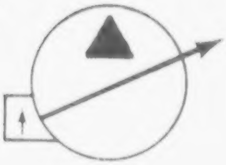
19. a.


Energy Triangle

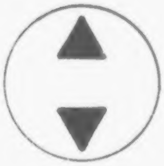
b.



c.



d.



20. Performance skills evaluated to the satisfaction of the instructor

VALVES
UNIT VIII

UNIT OBJECTIVE

After completion of this unit, the student should be able to select true statements concerning the operations of pressure reducing valves pressure compensated flow control valves, priority flow dividers, and proportional flow dividers, and discuss the operation of a needle valve as a flow control device and the flow paths in a directional control valve controlling a cylinder. The student should also be able to disassemble, inspect, and reassemble a pressure control valve, a flow control valve, and a directional control valve. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to valves with their correct definitions.
2. Name three categories of valves.
3. Name three types of pressure control valves.
4. Name the types of pressure relief valves when given a description of their operations.
5. Select true statements concerning the operation of a pressure reducing valve.
6. List three types of flow control valves.
7. Select true statements concerning the operation of a needle valve as a flow control device.
8. Select true statements concerning the operation of a pressure compensated flow control valve.
9. Select true statements concerning the operation of a priority flow divider.
10. Select true statements concerning the operation of a proportional flow divider.
11. Identify types of directional control valves.
12. Distinguish between the operation of a check valve and a spool direction control valve.

OBJECTIVE SHEET

13. Discuss the flow paths in a directional control valve controlling a cylinder.
14. Distinguish between open center and closed center systems.
15. Select types of actuators for directional control valves.
16. Identify symbols for hydraulic valves.
17. Demonstrate the ability to:
    a. Disassemble, inspect, and reassemble a pressure control valve. (Job Sheet #1)
    b. Disassemble, inspect, and reassemble a directional control valve. (Job Sheet #2)
    c. Disassemble, inspect, and reassemble a flow control valve. (Job Sheet #3).

VALVES
UNIT VIII

SUGGESTED ACTIVITIES

A. Provide students with objective sheet.

B. Provide students with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Demonstrate and discuss the procedures outlined in the job sheets.

F. Show students examples of valves.

G. Give test.

CONTENTS OF THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

  1. TM 1 — Operation of a Pressure Relief Valve
  2. TM 2 — Types of Pressure Relief Valves
  3. TM 3 — Operation of a Pressure Reducing Valve
  4. TM 4 — Operation of Flow Control Valves
  5. TM 5 — Types of Directional Control Valves
  6. TM 6 — Operation of Directional Control Valves
  7. TM 7 — Open and Closed Center Spool Valves (In Neutral)
  8. TM 8 — Symbols for Hydraulic Valves

D. Job sheets

  1. Job Sheet #1 — Disassemble, Inspect, and Reassemble a Pressure Control Valve
  2. Job Sheet #2 — Disassemble, Inspect, and Reassemble a Directional Control Valve
  3. Job Sheet #3 — Disassemble, Inspect, and Reassemble a Flow Control Valve.

CONTENTS OF THIS UNIT

E. Test

F. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Fundamentals of Service, Hydraulics.* Moline, IL: Deere and Company, 1967.

B. *Fluid Power I.* Cleveland, OH 44112: Parker Hannifin Corporation, 1975.

VALVES
UNIT VIII

INFORMATION SHEET

I. **Terms and definitions**

   A. Valve — A device which controls fluid flow directions, pressure, or flow rate

   B. Pressure control valve — A valve whose function is to control pressure

   C. Flow control valve — A valve whose function is to control flow rate

   D. Directional control valve — A valve whose primary function is to direct or prevent flow through selected passages

   E. Relief valve — A valve which is used to limit the maximum pressure in a hydraulic system

   F. Poppet — That part of certain valves which prevents flow when it closes against a seat

   G. Spool — A term loosely applied to almost any moving cylindrically shaped part of a hydraulic component which moves to direct flow through the component

   H. Pilot — An auxiliary valve used to control the operation of another valve; the controlling stage of a 2-stage valve

   I. Feathering — The operation of moving a valve through partial travel in order to get reduced flow rate

II. **Categories of valves**

   A. Pressure control

   B. Flow control

   C. Directional control

III. **Types of pressure control valves**

   A. Relief valve

      1. Simple

         Example: Cartridge valves and bypass valves

      2. Compound or pilot operated

   B. Pressure reducing

INFORMATION SHEET

IV. **Types and operation of pressure relief valves** (Transparency 1)

A. Simple (Transparency 2)

1. A spring holds a poppet against a seat

2. When the pressure in the system is large enough to overcome the spring force, the poppet moves off of the seat to allow fluid flow to the bypass

3. The spring tension is set so that the poppet opens to divert sufficient flow from the rest of the system and limit the pressure to a specified value

(NOTE: It is important to remember that pressure and flow in a hydraulic system are directly related.)

B. Compound (Transparency 2)

1. A spring holds the main stage spool so that the discharge port is normally blocked

2. A small amount of fluid flows past the main stage spool through a passage to another valve which is also part of the relief valve

(NOTE: This valve is known as the pilot valve.)

3. The pressure of the fluid emitted to the pilot valve creates a force on the pilot valve poppet

4. If this force is greater than the spring force then the poppet moves off its seat thus allowing a small amount of fluid to flow out the drain

5. The pressure resulting from flow past the pilot valve poppet is applied to the back side of the main stage spool

6. This pressure force on the spool plus the main stage spring force must be overcome by the system pressure on the front side of the main stage spool before this spool moves off its seat to allow flow to the discharge

(NOTE: Remember that force = pressure × area.)

7. In operation, the tension of the pilot stage spring is adjusted so that the main stage spool opens at some specified pressure

(NOTE: Although the compound relief valve is more complex than a simple relief valve, it is often used because it does a better job of limiting the system pressure to a specified value.)

INFORMATION SHEET

C. Pilot operated

1. The operation is similar to a compound relief valve except the pilot stage is not part of the relief valve package

2. A separate pilot valve in a remote location is used to adjust relief valve pressure

V. **Operation of a pressure reducing valve** (Transparency 3)

A. A pressure reducing valve controls the pressure in a secondary circuit to a specified value, and when the pressure in this circuit is low, the spool is fully open

B. The secondary circuit pressure acts on one side of the spool, and when the pressure is great enough to move the spool against the spring, the flow passage from the main to the secondary circuit is restricted

C. This operation will tend to regulate the pressure in the secondary as long as the main circuit pressure is greater than the desired secondary circuit pressure

D. The secondary circuit pressure can be adjusted by adjusting the spring tension

(NOTE: Only constant reduced pressure valves have been discussed. Some pressure reducing valves provide a fixed amount of pressure reduction (such as 500 PSI) across a valve. The operation of this valve is similar, except secondary circuit pressure is applied to both sides of the spool.)

VI. **Types of flow control valves**

A. Needle valve

(NOTE: This is also called a simple restrictor.)

B. Compensated flow control valve

C. Flow divider

VII. **Operation of a needle valve as a flow control device** (Transparency 4)

A. A needle valve serves as an adjustable means of regulating the flow to a secondary circuit (such as a motor or a cylinder) by restricting the fluid flow

B. As the knob on the needle valve is turned a needle is lowered into the fluid stream

C. With the knob turned to its extreme position the needle closes onto a seat restricting the fluid flow

(NOTE: A needle valve is considered an uncompensated flow control device because flow will increase if the inlet pressure increases.)

INFORMATION SHEET

VIII. **Operation of a pressure compensated flow control valve** (Transparency 4)

A. Flow through a fixed orifice in the inlet causes a pressure drop

B. The full inlet pressure is applied to the inlet side and a reduced pressure is applied to the spring side of the spool

C. If the force created by the pressure differences is greater than the spring force, the valve spool moves to close the outlet orifice and thus reduce the flow rate

D. The system functions to maintain a constant pressure drop across the inlet orifice, and if this pressure is controlled, then the flow will be controlled

E. The flow may be varied by varying the spring tension

IX. **Operation of a priority flow divider** (Transparency 4)

A. A priority flow divider functions to supply a regulated flow to the priority output, and the remaining flow is routed to the secondary circuit

B. As the flow divider spool slides in its bore, one outlet is opened wider when the other is closed off

C. Fluid from the inlet is metered through an orifice in the spool, causing a pressure drop which tends to displace the spool to close off the priority outlet, and this displacement is resisted by the spring

D. The spool will position to maintain a constant pressure drop across the spool orifice and thus a constant flow to the priority outlet

E. The secondary outlet will be opened to receive the remaining flow that is available

(NOTE: A priority flow divider is used in circuits where flow must be maintained to some part of the circuit. A common example is when a single pump is both used to supply steering and used to insure that a constant flow rate, say 2 GPM, to the steering. Any remaining flow is then available to the auxiliary circuits.)

X. **Operation of a proportional flow divider** (Transparency 4)

A. A proportional flow divider is used to divide the flow into two circuits

B. Fluid from the inlet flows through two orifices (one on each side of the spool) causing a pressure drop across the two orifices; the resulting pressure is applied to each side of the spool

C. If the pressure drop across the two orifices is not equal the spool shifts and changes the restriction at the outlet orifice

D. The valve functions to maintain equal pressure drop across the inlet orifices

(NOTE: The ratio of the flow from the two outlets is set by the size of the two inlet orifices. Equal orifice sizes result in equal flow rates.)

INFORMATION SHEET

XI. **Types of directional control valves** (Transparency 5)

- A. Check valve
- B. Rotary valve
- C. Spool valve

XII. **Operation of a check valve and a spool direction control valve** (Transparency 6)

- A. Check valve
  1. Only allows fluid to flow in one direction, from inlet to outlet
  2. When pressure is applied to the inlet, it causes the valve to open against the spring allowing flow to pass
  3. When pressure is applied to the outlet side of the check valve, the valve is held firmly against its seat thus blocking fluid flow in this direction
- B. Spool direction control valve
  1. A directional control valve serves to "direct" the fluid from a pump to an actuator such as a motor or cylinder
  2. Lands on spool are used to open or close openings to passages in the valve body

XIII. **Flow paths in a directional control valve controlling a cylinder** (Transparency 6)

- A. Valve shifted to extend cylinder
  1. The handle is moved to the left and the lands open flow passages from the pump to the head side of the cylinder
  2. A flow passage from the rod side of the cylinder is opened to route this flow to the reservoir
- B. Valve shifted to retract the cylinder
  1. The valve is moved to the right and lands open flow passages from the pump to the rod side of the cylinder
  2. A flow passage from the head side of the cylinder is opened to route this to the reservoir

INFORMATION SHEET

XIV. **Fluid flow in directional control valves in the neutral position** (Transparency 7)

A. Open center

1. These valves have lands which direct the pump to the reservoir when the valve is in the neutral position

2. The lands may be positioned on the spool to block flow from both sides of the cylinder (as shown in Transparency 8) or allow flow to pass from one side to the other side of the cylinder

(NOTE: These are called open center valves. These are used with fixed displacement pumps (constant flow pumps). Such systems are called open center systems.)

B. Closed center

1. The lands are positioned on the spool to block flow from the pump when the valve is in the neutral position

2. The lands may be positioned on the spool to block flow from both sides of the cylinder, or allow flow to pass from one side to the other side of the cylinder

XV. **Types of actuators for directional control valves**

A. Hand lever

B. Electrical solenoid

(NOTE: This allows an electric signal to shift the valve to either extreme.)

C. Servo valve

(NOTE: This allows an electric signal to shift the valve to various intermediate positions.)

D. Pilot operated

(NOTE: This allows hydraulic pressure to shift the valve.)

XVI. **Symbols for hydraulic valves** (Transparency 8)

A. Pressure control

1. Relief valve

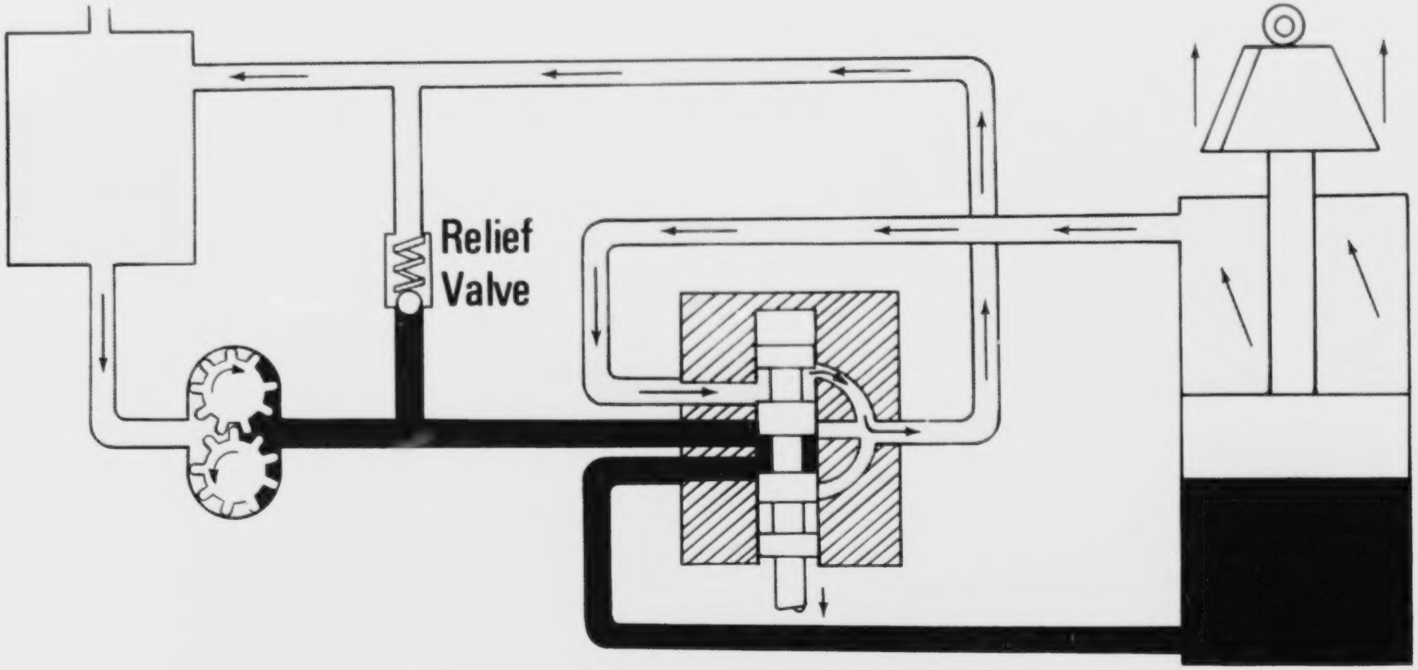
2. Pressure reducing valve

INFORMATION SHEET

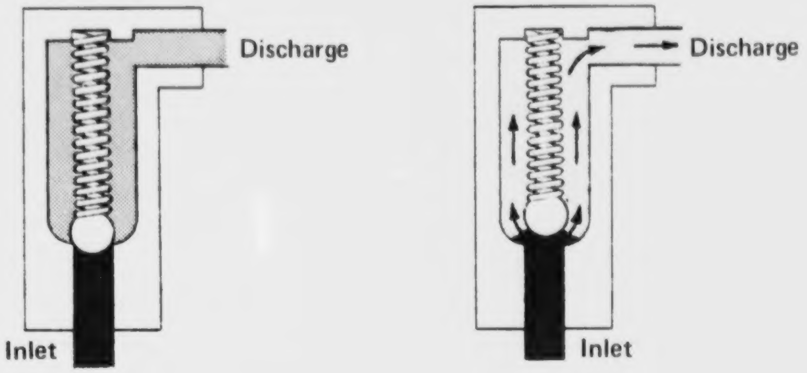
B. Flow control
    1. Restrictor
    2. Pressure compensated flow control

C. Directional control
    1. Check valve
    2. Spool valves
        a. 3 position, 4 way open center
        b. 3 position, 4 way closed center

Operation of a Pressure Relief Valve


Relief
Valve

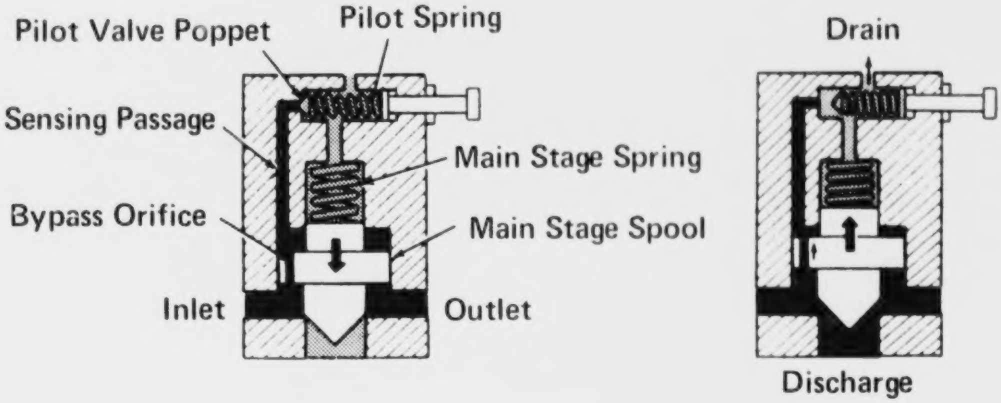
Types of Pressure Relief Valves


Discharge
Inlet
Discharge
Inlet

Closed

Open

Simple

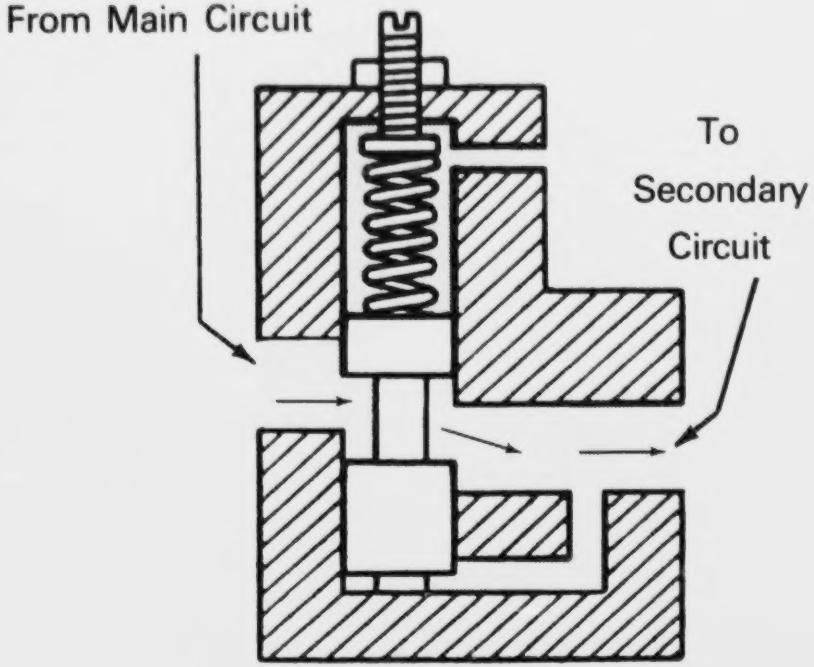

Pilot Valve Poppet
Pilot Spring
Sensing Passage
Main Stage Spring
Bypass Orifice
Main Stage Spool
Inlet
Outlet
Drain
Discharge

Closed

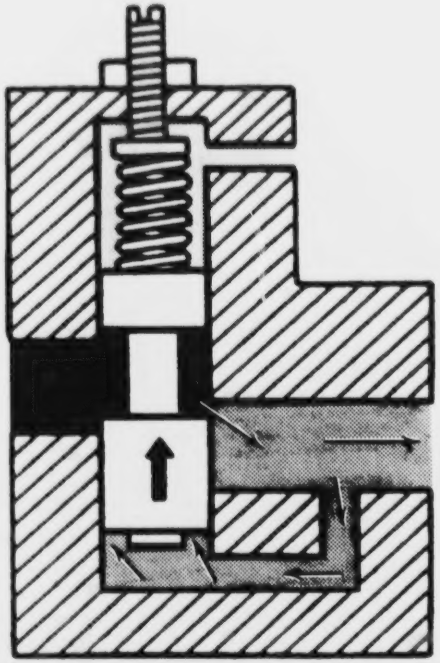
Open

Compound

Operation of a Pressure Reducing Valve

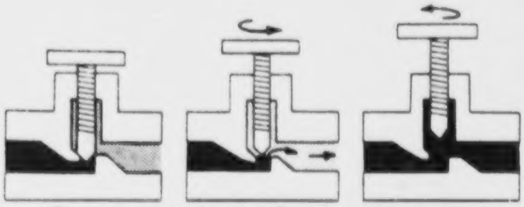

From Main Circuit
To Secondary Circuit

Valve Open,
Not Operating



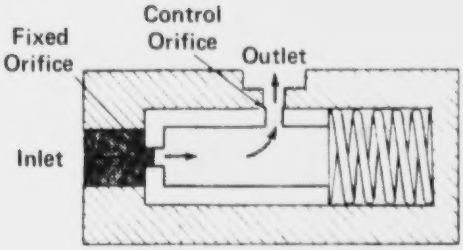
Valve Partly Closes
to Reduce Pressure

Operation of Flow Control Valves

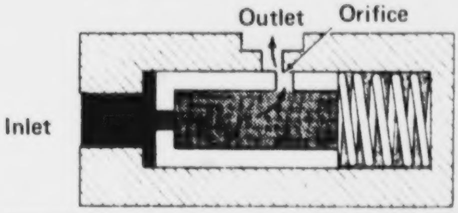


Closed Partly Open Wide Open

Needle Valve

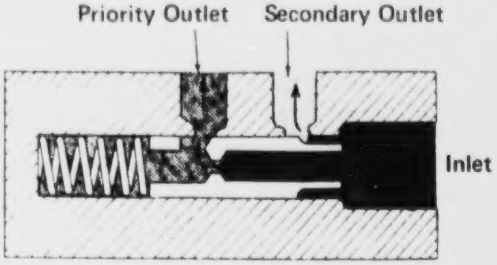

Fixed Orifice
Control Orifice
Outlet
Inlet

Control Orifice Fully Open

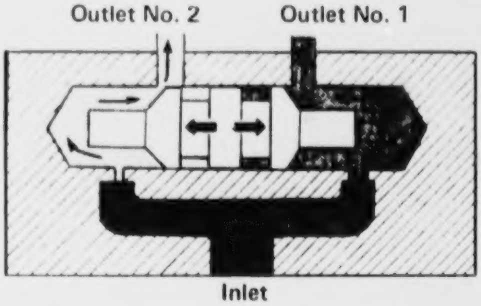

Outlet
Orifice
Inlet

Control Orifice Partly Closed (Compensating)

Pressure Compensated Flow Control Valve

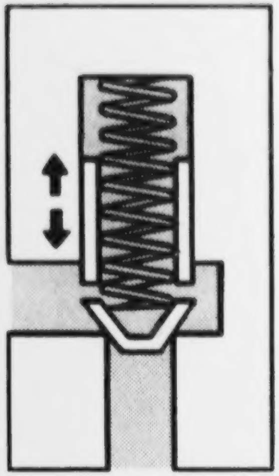

Priority Outlet
Secondary Outlet
Inlet

Priority Flow Divider

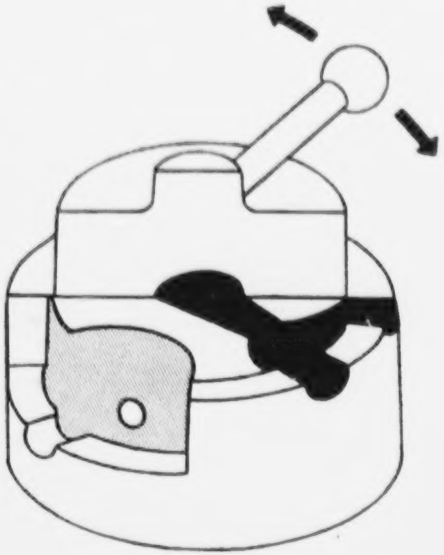

Outlet No. 2
Outlet No. 1
Inlet

Proportional Flow Divider

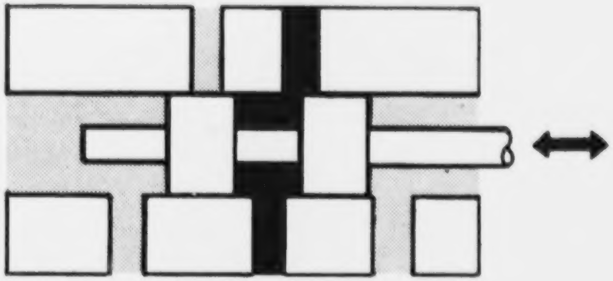
Types of Directional Control Valves



Check Valve

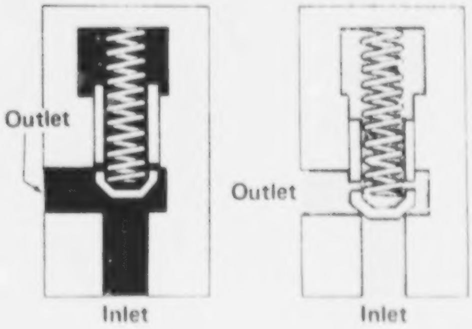


Rotary Valve



Spool Valve

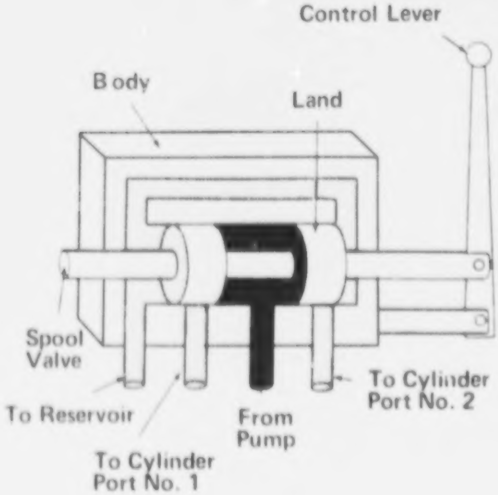
Operation of Directional Control Valves


Outlet
Inlet
Outlet
Inlet

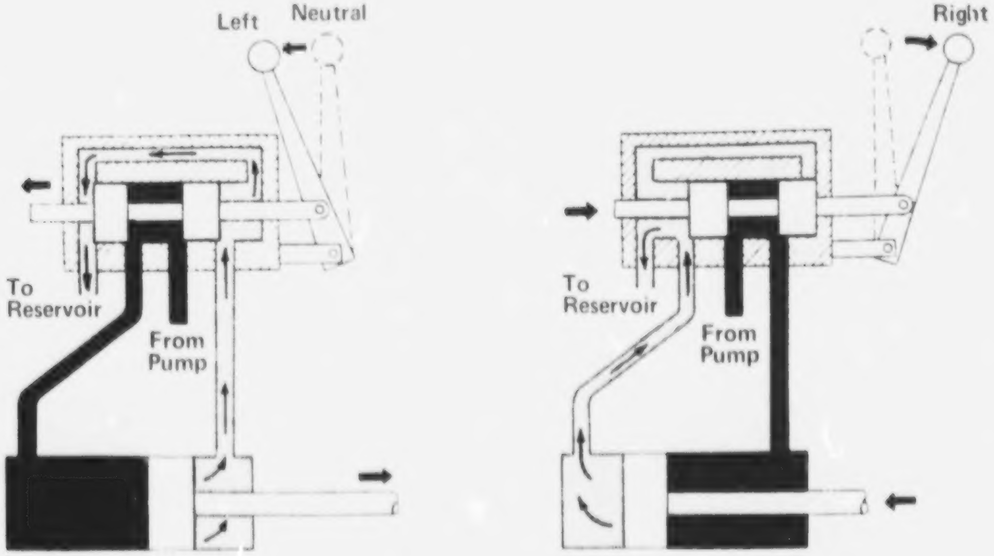
Open

Closed

Check Valve
In Operation


Control Lever
Body
Land
Spool Valve
To Reservoir
To Cylinder Port No. 1
From Pump
To Cylinder Port No. 2

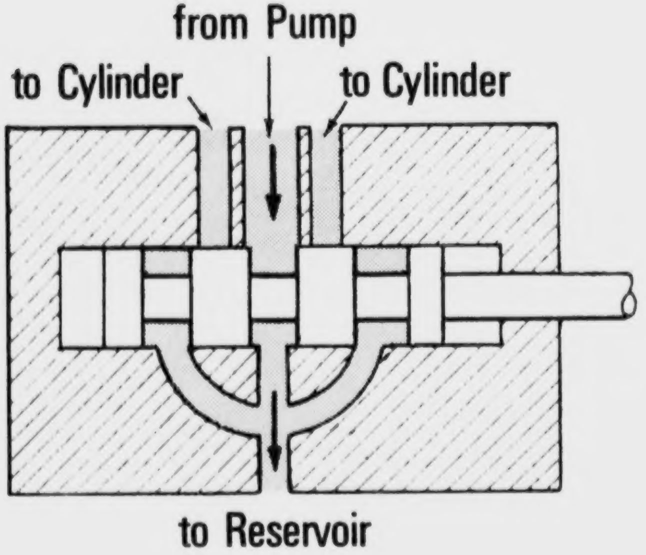
Spool Directional Valve


Left
Neutral
To Reservoir
From Pump
Right
To Reservoir
From Pump

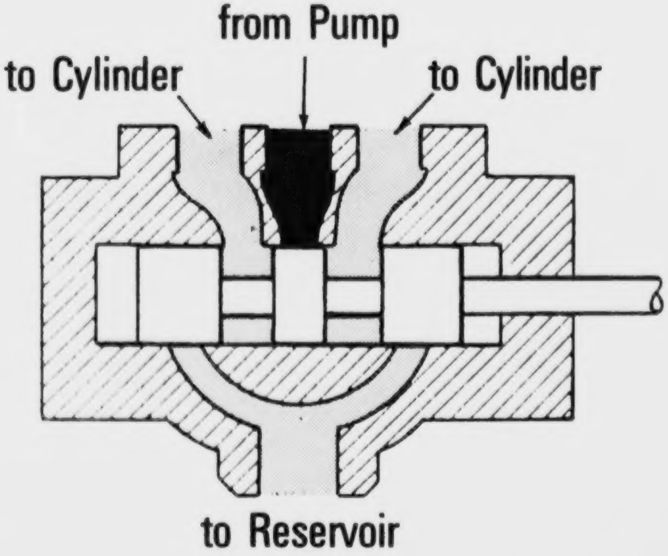
Spool Valve Directing Oil to Cylinder

Open and Closed Center Spool Valves

(In Neutral)


from Pump
to Cylinder
to Cylinder
to Reservoir

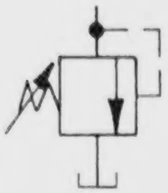
Open Center


from Pump
to Cylinder
to Cylinder
to Reservoir

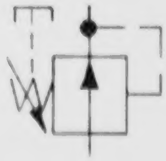
Closed Center

Symbols for Hydraulic Valves

Pressure Control

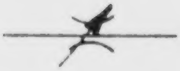


Relief Valve

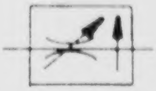


Pressure Reducing Valve

Flow Control

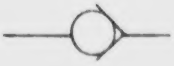


Restrictor

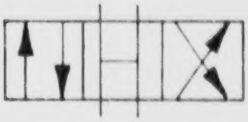


Pressure Compensated
Flow Contol

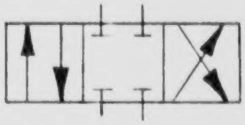
Directional Control



Check Valve



3 Position, 4 Way
Open Center
Spool Valve



3 Position, 4 Way
Closed Center
Spool Valve

VALVES
UNIT VIII

JOB SHEET #1 — DISASSEMBLE, INSPECT, AND REASSEMBLE A PRESSURE CONTROL VALVE

A. Tools and materials

1. Pressure control valve
2. Service manual (if available)
3. Hand tool set
4. Solvent
5. Lint free shop towels
6. Safety glasses

B. Routine #1 — Disassemble the valve

1. Remove the valve adjustor screw
2. Remove the valve spring
3. Remove the valve spool or poppet
4. If the valve is a compound valve remove the main stage spring and spool

☐ Have your instructor check your work

C. Routine #2 — Inspect the valve

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Inspect the spool(s) or poppet and body for unusual wear		
2. Inspect any O-ring seals for nicks and breaks, and replace if necessary		
3. Inspect internal fluid passages then clean with solvent		

☐ Have your instructor check your work

JOB SHEET #1

D. Routine #3 — Reassemble the valve

(NOTE: Lube components prior to reasembly.)

1. Install main stage spool and spring if compound valve
2. Install poppet or spool
3. Install spring
4. Replace adjustor screw and tighten only partially into valve body

☐ Have your instructor check your work

5. Clean up area and return tools and materials to proper storage

VALVES
UNIT VIII

JOB SHEET #2 — DISASSEMBLE, INSPECT, AND REASSEMBLE A DIRECTIONAL CONTROL VALVE

A. Tools and materials

1. Directional control valve

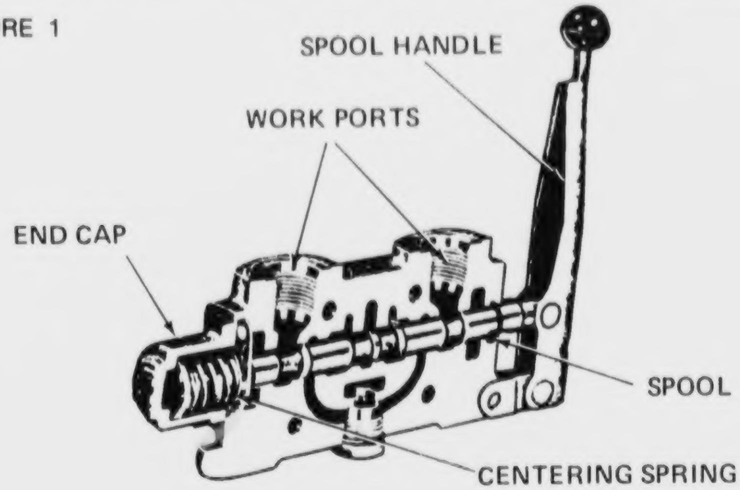
   (NOTE: This procedure assumes that a manually operated directional control valve will be used. Other types of directional control valves may be used with minor changes to this procedure.)

2. Service manual if available
3. Hand tools
4. Lint free shop towels
5. Shipping plugs for open ports
6. Safety glasses

B. Routine #1 — Disassemble the valve

(NOTE: Figure 1 shows a cut-away view of a typical directional control valve.)

FIGURE 1



(NOTE: Be sure spools are replaced into the openings from which they were removed.)

1. Install the shipping plugs into the valve ports
2. Clean the external surfaces of the valve with solvent

JOB SHEET #2

3. Place the valve in a clean area for disassembly
4. Remove the spool handle if not already removed
5. Remove the end cap
6. Remove the nut that holds the centering spring and remove spring
7. Carefully slide the spool from the valve body

☐ Have your instructor check your work

C. Routine #2 — Inspect the valve

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Examine the spool for excessive wear (NOTE: The lands on the spool may become eroded from forces resulting from the fluid flow. Wear can also occur from contaminated fluid.)		
2. Examine the spool O-ring seals, and replace if worn or nicked		
3. Examine the valve body for cracks		

☐ Have your instuctor check your work

D. Routine #3 — Reassemble the valve

(NOTE: Lubricate all components during reassembly.)

1. Carefully install the spool into the valve body, and use special care to insure that the O-rings are not damaged during installation
2. Install the centering spring and washers (if used) and retaining nut
3. Tighten nut
4. Install end cap
5. Install spool handle

☐ Have your instructor check your work

6. Clean up area and return tools and materials to proper storage

VALVES
UNIT VIII

JOB SHEET #3 — DISASSEMBLE, INSPECT, AND REASSEMBLE A FLOW CONTROL VALVE

A. Tools and materials

1. Flow control valve
2. Service manual (if available)
3. Hand tool set
4. Solvent
5. Lint free shop towels
6. Safety glasses
7. Shipping plugs

B. Routine #1 — Disassemble the valve

1. Place shipping plugs into the valve ports
2. Clean the external surfaces
3. Place the valve on a clean surface for disassembly
4. Remove the spring retainer cap
5. Remove the spring and spool

☐ Have yor instructor check your work

C. Routine #2 — Inspect the valve

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Examine any O-ring seals, and replace		
2. Inspect spool for excessive wear		
3. Inspect spool body for unusual wear		

☐ Have your instructor check your work

JOB SHEET #3

D. Routine #3 — Reassemble the valve

(NOTE: Lubricate all parts during reassembly.)

1. Clean all internal surfaces with the solvent
2. Install the spool taking care not to damage the O-ring seals
3. Install the spring
4. Replace the spring retainer cap

☐ Have your instructor check your work

5. Clean up area and return tools and materials to proper storage

VALVES
UNIT VIII

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. A valve whose primary function is to direct or prevent flow through selected passages

_____b. A term loosely applied to almost any moving cylindrically shaped part of a hydraulic component which moves to direct flow through the component

_____c. A valve whose function is to control pressure

_____d. An auxiliary valve used to control the operation of another valve; the controlling stage of a 2-stage valve

_____e. A device which controls fluid flow directions, pressure, or flow rate

_____f. A valve whose function is to control flow rate

_____g. That part of certain valves which prevents flow when it closes against a seat

_____h. A valve which is used to limit the maximum pressure in a hydraulic system

_____i. The operation of moving a valve through partial travel in order to get reduced flow rate

1. Poppet
2. Pressure control valve
3. Spool
4. Directional control valve
5. Feathering
6. Flow control valve
7. Relief valve
8. Pilot
9. Valve

2. Name three categories of valves.

a. ______________________________

b. ______________________________

c. ______________________________

TEST

3. Name three types of pressure control valves.

   a. ______________________________

      1) ______________________________

      2) ______________________________

   b. ______________________________

4. Name the types of pressure relief valves for the following operations:

   a. ______________________________

      1) The operation is similar to a compound relief valve except the pilot stage is not part of the relief valve package

      2) A separate pilot valve in a remote location is used to adjust relief valve pressure

   b. ______________________________

      1) A spring holds a poppet against a seat

      2) When the pressure in the system is large enough to overcome the spring force, the poppet moves off of the seat to allow fluid flow to the bypass

      3) The spring tension is set so that the poppet opens to divert sufficient flow from the rest of the system and limit the pressure to a specified value

   c. ______________________________

      1) A spring holds the main stage spool so that the discharge port is normally blocked

      2) A small amount of fluid flows past the main stage spool through a passage to another valve which is also part of the relief valve

      3) The pressure of the fluid emitted to the pilot valve creates a force on the pilot valve poppet

      4) If this force is greater than the spring force then the poppet moves off its seat thus allowing a small amount of fluid to flow out the drain

      5) The pressure resulting from flow past the pilot valve poppet is applied to the back side of the main stage spool

      6) This pressure force on the spool plus the main stage spring force must be overcome by the system pressure on the front side of the main stage spool before the spool moves off its seat to allow flow to the discharge

      7) In operation, the tension on the pilot stage spring is adjusted so that the main stage spool opens at some specified pressure

TEST

5. Select true statements concerning the operation of a pressure reducing valve by placing an "X" in the appropriate blanks.

   _____a. A pressure reducing valve controls the pressure in a secondary circuit to a specified value, and when the pressure in this circuit is low, the spool is fully open

   _____b. The secondary circuit pressure acts on both sides of the spool, and when this pressure is great enough to move the spool against the spring, the flow passage from the main to the secondary circuit is completely open

   _____c. The secondary circuit pressure can be adjusted by adjusting the spring tension

6. List three types of flow control valves.

   a. ______________________________

   b. ______________________________

   c. ______________________________

7. Select true statements concerning the operation of a needle valve as a flow control device by placing an "X" in the appropriate blanks.

   _____a. A needle valve serves as an adjustable means of regulating the flow to a secondary circuit by restricting the fluid flow

   _____b. As the knob on the needle valve is turned a needle is lowered into the fluid stream

   _____c. With the knob turned to its extreme position the needle closes onto a seat restricting the fluid flow

8. Select true statements concerning the operation of a pressure compensated flow control valve by placing an "X" in the appropriate blanks.

   _____a. Flow through a fixed orifice in the inlet causes a pressure rise

   _____b. The full inlet pressure is applied to the inlet side and a reduced pressure is applied to the spring side of the spool

   _____c. If the force created by the pressure differences is greater than the spring force, the valve spool moves to close the outlet orifice and thus reduce the flow rate

   _____d. The system functions to maintain a constant pressure rise across the inlet orifice, and if this pressure rise is controlled, then the flow will be controlled

   _____e. The flow may be varied by varying the spring tension

TEST

9. Select true statements concerning the operation of a priority flow divider by placing an "X" in the appropriate blanks.

______a. A priority flow divider functions to supply a regulated flow to the priority output, and the remaining flow is routed to the secondary circuit

______b. As the flow divider spool slides in its bore, both outlets are opened

______c. Fluid from the inlet is metered through an orifice in the spool, causing a pressure drop which tends to displace the spool to close off the priority outlet, and this displacement is resisted by the spring

______d. The spool will position to maintain a constant pressure drop across the spool orifice and thus a constant flow to the priority outlet

______e. The primary outlet will be opened to receive the remaining flow that is available

10. Select true statements concerning the operation of a proportional flow divider by placing an "X" in the appropriate blanks.

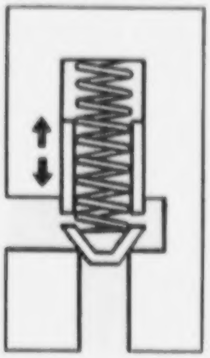
______a. A proportional flow divider is used to divide the flow into three circuits

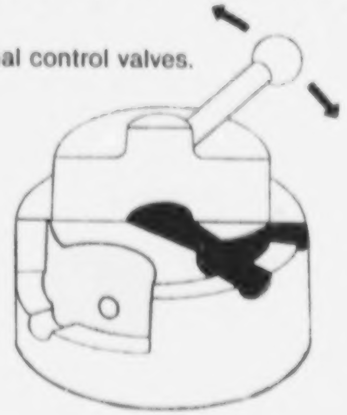
______b. Fluid from the inlet flows through two orifices causing a pressure drop across the two orifices; the resulting pressure is applied to each side of the spool

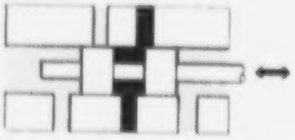
______c. If the pressure drop across the two orifices is not equal the spool shifts and changes the restriction at the outlet orifice

______d. The valve functions so that inlet orifices have an unequal pressure drop across them

11. Identify the types of directional control valves.







a. ______________________ b. ______________________ c. ______________________

TEST

12. Distinguish between the operation of a check valve and a spool direction control valve by placing an "X" next to the descriptions which apply to the operation of a check valve.

_____a. Serves to "direct" the fluid from a pump to an actuator such as a motor or cylinder

_____b. When pressure is applied to the inlet, it causes the valve to open against the spring allowing flow to pass

_____c. Lands on spool are used to open or close openings to passages in the valve body

_____d. Only allows fluid to flow in one direction, from inlet to outlet

_____e. When pressure is applied to the outlet side, the valve is held firmly against its seat thus blocking fluid flow in this direction

13. Discuss the flow paths in a directional control valve controlling a cylinder.

a. Valve shifted to extend cylinder________________________________

____

____

____

b. Valve shifted to retract the cylinder________________________________

____

____

____

14. Distinguish between open and closed center systems by placing an "O" next to the descriptions which apply to open center systems and a "C" next to descriptions which apply to closed center systems.

(NOTE: Some descriptions may apply to both systems.)

_____a. The lands may be positioned on the spool to block the flow from both sides of the cylinder, or allow flow to pass from one side to the other side of the cylinder

_____b. The lands are positioned on the spool to block flow from the pump when the valve is in the neutral position

_____c. These valves have lands which direct the pump to the reservoir when the valve is in the neutral position

TEST

15. Select types of actuators for directional control valves by placing an "X" in the appropriate blanks.

______a. Hand lever

______b. Electrical solenoid

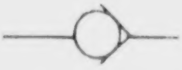
______c. Relief valve

______d. Servo valve

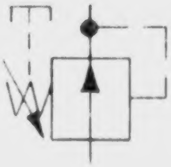
______e. Open center valve

______f. Pilot operated

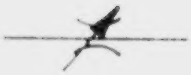
16. Identify the symbols for hydraulic valves.



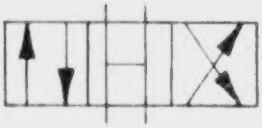
a. ________________________________



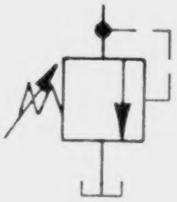
b. ________________________________



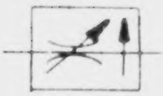
c. ________________________________



d. ________________________________

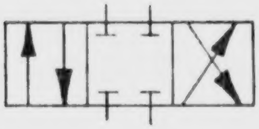


e. ________________________________



f. ________________________________

TEST



g. ________________________________

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

17. Demonstrate the ability to:

    a. Disassemble, inspect, and reassemble a pressure control valve.

    b. Disassemble, inspect, and reassemble a directional control valve.

    c. Disassemble, inspect, and reassemble a flow control valve.

VALVES
UNIT VIII

ANSWERS TO TEST

1. a. 4 e. 9 i. 5
   b. 3 f. 6
   c. 2 g. 1
   d. 8 h. 7

2. a. Pressure control
   b. Flow control
   c. Directional control

3. a. Relief valve
      1) Simple
      2) Compound or pilot operated
   b. Pressure reducing

4. a. Pilot operated
   b. Simple
   c. Compound

5. a, c

6. a. Needle valve
   b. Compensated flow control valve
   c. Flow divider

7. a, b, c

8. b, c, e

9. a, c, d

10. b, c

11. a. Check valve
    b. Rotary valve
    c. Spool valve

12. b, d, e

13. Discussion should include:
    a. Valve shifted to extend cylinder
       1) The handle is moved to the left and the lands open flow passages from the pump to the head side of the cylinder
       2) A flow passage from the rod side of the cylinder is opened to route this flow to the reservoir

ANSWERS TO TEST

   b. Valve shifted to retract the cylinder
      1) The valve is moved to the right and lands open flow passages from the pump to the rod side of the cylinder
      2) A flow passage from the head side of the cylinder is opened to route this to the reservoir

14. a. O, C
    b. C
    c. O

15. a, b, d, f

16. a. Check valve
    b. Pressure reducing valve
    c. Restrictor
    d. 3 position, 4 way open center spool valve
    e. Relief valve
    f. Pressure compensated flow control valve
    g. 3 position, 4 way closed center spool valve

17. Performance skills evaluated to the satisfaction of the instructor

CYLINDERS
UNIT IX

UNIT OBJECTIVE

After completion of this unit, the student should be able to calculate the force output, speed, and power output of a hydraulic cylinder. The student should also be able to disassemble, inspect, and reassemble a hydraulic cylinder and test a hydraulic cylinder for internal and external leakage. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to cylinders with their correct definitions.
2. Discuss the operation of a hydraulic cylinder.
3. Distinguish between the operation of single-acting and double-acting cylinders.
4. Identify types of double-acting cylinders.
5. Identify the parts of a single-acting cylinder.
6. Identify the parts of a double-acting cylinder.
7. List sources of common failures of hydraulic cylinders.
8. Given a formula, calculate the force output of a hydraulic cylinder.
9. Given a formula, calculate the speed of a hydraulic cylinder.
10. Given a formula, calculate the power output of a cylinder.
11. Given a formula, calculate the flow rate required to move a cylinder a given distance in a given time.
12. Draw the symbol for a cylinder.
13. Demonstrate the ability to:
    a. Disassemble, inspect, and reassemble a hydraulic cylinder. (Job Sheet #1)
    b. Test a cylinder for internal and external leakage. (Job Sheet #2)

CYLINDERS
UNIT IX

SUGGESTED ACTIVITIES

A. Provide students with objective sheet.

B. Provide students with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Give test.

CONTENTS OF THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

  1. TM 1 — Operation of a Hydraulic Cylinder
  2. TM 2 — Operation of Single and Double-Acting Cylinders
  3. TM 3 — Types of Double-Acting Hydraulic Cylinders
  4. TM 4 — Single-Acting Cylinder
  5. TM 5 — Double-Acting Cylinder

D. Job sheets

  1. Job Sheet #1 — Disassemble, Inspect, and Reassemble a Hydraulic Cylinder
  2. Job Sheet #2 — Test a Cylinder for Internal and External Leakage

E. Test

F. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Fundamentals of Service, Hydraulics.* Moline, IL: Deere and Company, 1967.

B. *Analyzing Hydraulic Systems.* Cleveland, OH 44112: Parker Hannifin Corporation, 1976.

C. *Fluid Power Designers' Lightning Reference Handbook.* Orange, CA: Paul-Munroe Hydraulics, Inc., 1976.

D. *Fluid Power 2.* Cleveland, OH 44112: Parker Hannifin Corporation, 1975.

CYLINDERS
UNIT IX

INFORMATION SHEET

I. **Terms and definitions**

   A. Cylinder — An actuator which converts hydraulic power into linear mechanical force and motion

   B. Piston area — Area of the cylinder piston

   C. Rod area — Area of the piston rod

   D. Rod side area — Effective area on the rod side of the cylinder; equal to the piston area minus the rod area

   E. Back pressure — Pressure in the return lines caused by flow in these lines

II. **Operation of a hydraulic cylinder** (Transparency 1)

   A. Hydraulic oil flows into a chamber of the cylinder, causing the cylinder rod to move

   B. Pressure of the fluid acting on the surface of a piston creates a force on the rod

III. **Operation of single and double-acting cylinders** (Transparency 2)

   A. Single-acting

      1. Oil flows into only one side of the cylinder

      2. The cylinder is retracted by gravity or a spring

   B. Double-acting

      1. Oil flows into one side to extend the cylinder

      2. The cylinder is retracted by oil flow into the other side of the cylinder

IV. **Types of double-acting cylinders** (Transparency 3)

   A. Balanced

   (NOTE: A balanced double-acting cylinder has an equal area on both sides of piston.)

   B. Unbalanced

   (NOTE: Unbalanced double-acting cylinders have unequal areas on each side of the piston.)

INFORMATION SHEET

V. **Parts of a single-acting cylinder** (Transparency 4)

   A. Piston

   B. Piston rod

   C. Piston seal

   D. Rod wiper seal

   E. Air vent

   F. Oil inlet

   G. Cylinder housing

   H. Cylinder bore

   I. Mount

VI. **Parts of a double-acting cylinder** (Transparency 5)

   A. Piston

   B. Piston rod

   C. Piston seals

   D. Oil ports

   E. End cap

   F. Rod (pressure) seal

   G. Cylinder housing

   H. Cylinder bore

   I. Mount

   J. Wiper seal

VII. **Sources of common failures of hydraulic cylinders**

   A. Bent rod

   B. Scored cylinder barrel

   C. Nicked or damaged rod

   D. Leaking piston seal

INFORMATION SHEET

E. Leaking rod seal

F. Defective wiper seal

(NOTE: A defective wiper seal will often cause a leaking piston or rod seal or other problem.)

VIII. The force output of hydraulic cylinders

A. Single-acting — Force = Pressure × Piston Area or $F = PA$

Example: Calculating force when pressure and area are known
Pressure = P = 1500 Pounds per Square Inch (PSI)
Piston diameter = D = 3.0 inches

(NOTE: $\pi = 3.14$)

Piston area = $A = \pi D^2/4 = 3.14(3)^2/4 = 7.07$ sq. in.

Force = F = 1500 lbs./sq. in. × 7.07 sq. in. = 10,600 lbs.

Example: Calculating pressure when force and diameter are known

Force = 5,000 lbs.
Piston Diameter = 2.0 inches

Piston area = $A = \pi D^2/4 = 3.14\left(\frac{2^2}{4}\right) = 3.14$ sq. in.

$$\text{Pressure} = P = \frac{F}{A} = \frac{5{,}000}{3.14 \text{ sq. in.}} = 1590 \text{ PSI}$$

B. Double-acting — Force = Piston Area × Piston Pressure
Rod side Area × Rod side Pressure

Example: Piston diameter = 4 inches
Rod diameter = 2 inches
Piston pressure = 1500 Pounds per Square Inch (PSI)
Rod-side pressure = 500 Pounds per Square Inch PSI)

Piston area = $\pi D^2/4 = 3.14\,(4)^2/4 = 12.6$ sq. in.

Rod area = $(3.14)\,(2)^2/4 = 3.14$ sq. in.
Rod-side area = $12.56 - 3.14 = 9.42$ sq. in.

$$F = \left(1500\,\frac{\text{lbs.}}{\text{sq. in.}}\right) \times (12.6 \text{ sq. in.}) - \left(500\,\frac{\text{lbs.}}{\text{sq. in.}}\right)(9.42 \text{ sq. in.})$$

F = 14,190 lbs.

INFORMATION SHEET

IX. Formulas for speed of a cylinder

A. Single-acting —

$$\text{Rod speed} = \frac{\text{flow rate} \times 19.25}{\text{Piston Area}} \text{ or } V = \frac{Q \times 19.25}{A}$$

(NOTE: This equation requires that the unit of measure of flow rate be GAL/MIN (GPM) and unit of measure of piston area be square inches. The rod speed will be in feet per minute.)

Example: Flow rate into cylinder = Q = 5GPM
Piston Diameter = D = 3

Then: Piston Area = $3.14\,(3)^2/4 = 7.07$ sq. in.

$$V = \frac{Q \times 19.25}{A} = \frac{5\ \text{Gal/Min} \times 19.25}{7.07\ \text{sq. in.}} = 13.6\ \text{ft/min.}$$

B. Double-acting —

$$\text{Rod speed} = \frac{\text{flow rate} \times 19.25}{\text{Area}} \text{ or } V = \frac{Q \times 19.25}{A}$$

where the area is the piston area when the rod is extending and the rod-side area when the piston is retracting

Example:
Piston diameter = 4 inches
Rod diameter = 2 inches
Piston area = 12.6 sq. in.
Rod area = 3.14 sq. in.
Rod-side area = 9.42 sq. in.

If the cylinder is extending and the flow into the piston side is 10 GPM, then:

$$V = \frac{10\ \text{GPM} \times 19.25}{12.6\ \text{sq. in.}} = 15.3\ \text{ft/min.}$$

If the cylinder is retracting and the flow into the rod side is 10 GPM, then:

$$V = \frac{10\ \text{GPM} \times 19.25}{9.42\ \text{sq. in.}} = 20.4\ \text{ft/min.}$$

INFORMATION SHEET

X. Formula for power output of a cylinder —

$$\text{Power} = \frac{V \times F}{33{,}000}$$

Where: V = Rod velocity (ft/sec)
F = Rod force (pounds force)
Power = Power Out (Horsepower)

Example:
V = 10 ft/sec
F = 5000 pounds force

$$\text{Power} = \frac{(10)(15000)}{33000} = 4.5 \text{ HP}$$

XI. Formula for the flow rate required to move a cylinder a given distance in a given time —

$$Q = \frac{A \times L}{T \times 231}$$

Where: Q = Flow rate in gallons per minute (GPM)
A = Area in square inches (in^2) L = Length in inches (in) T = Time in minutes

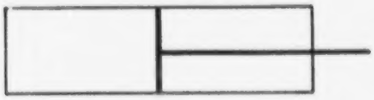
Example:

To move a 2 inch diameter cylinder 20 inches in # minute the flow rate required is 0.54 GPM.

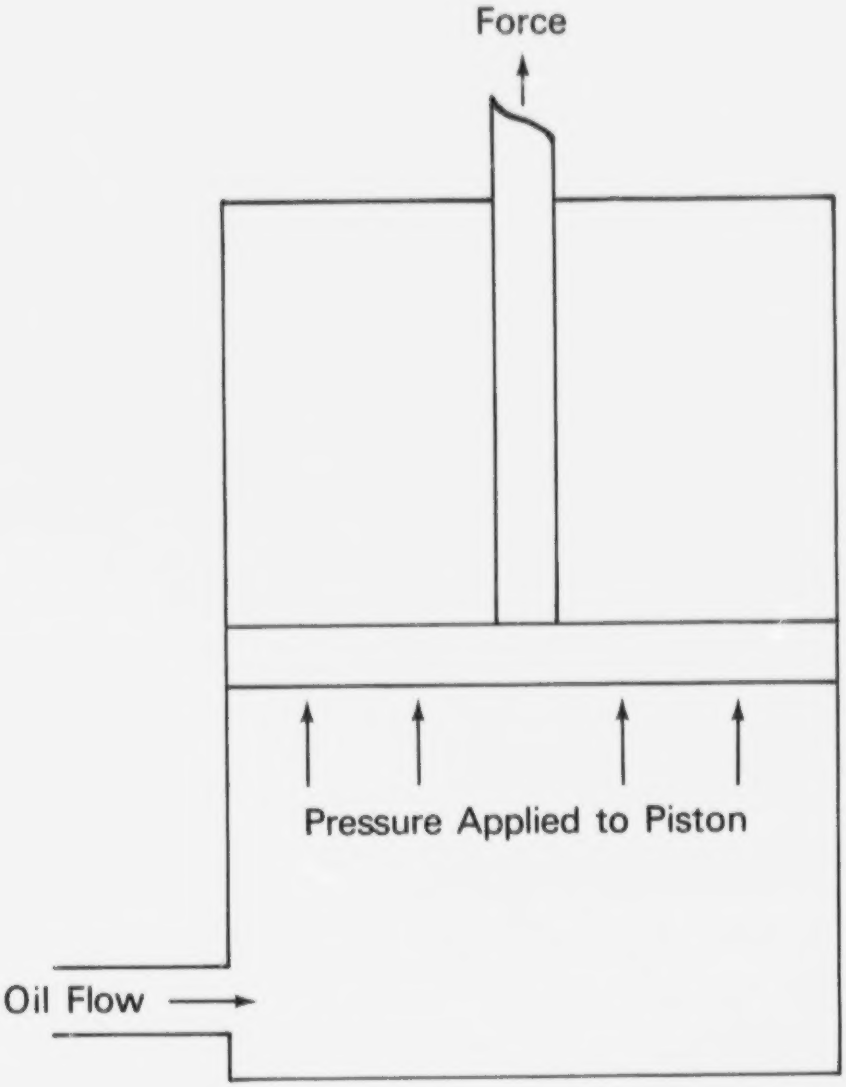
$$A = \frac{\pi D^2}{4} = \frac{3.14(2^2)}{4} = 3.14 \text{ in}^2$$

$$Q = \frac{(3.14) \times 20 \text{ inches}}{0.5 \text{ minutes} \times 231} = 0.54 \text{ GPM}$$

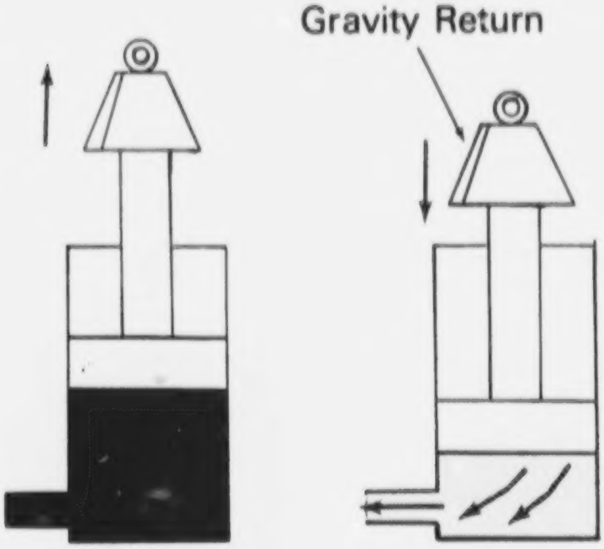
XII. Symbol for a cylinder



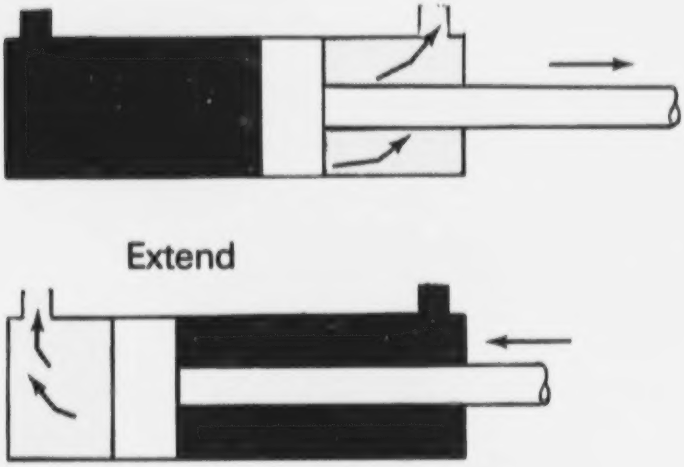
Operation of a Hydraulic Cylinder


Force
Pressure Applied to Piston
Oil Flow

Operation of Single and Double Acting Cylinders

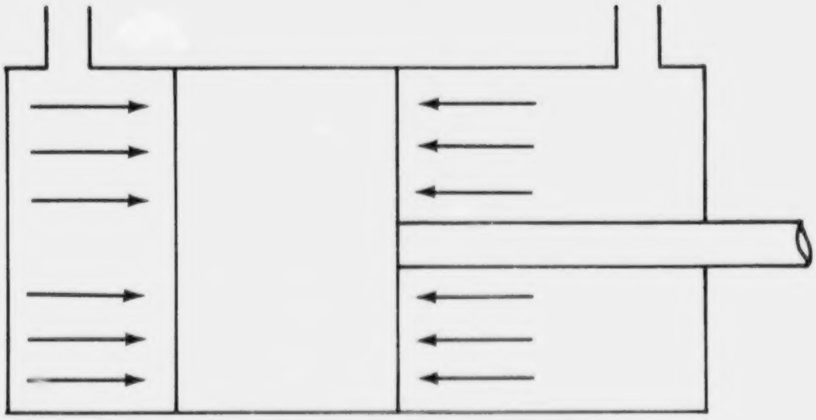

Gravity Return
Raise
Lower

Single-Acting

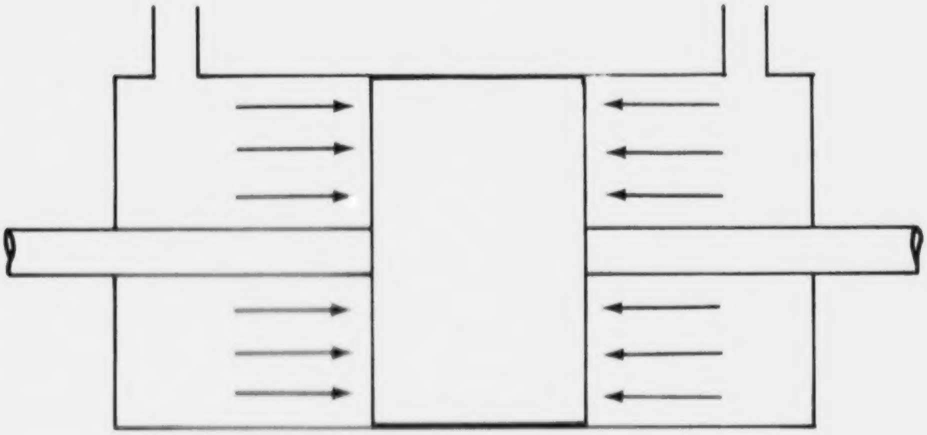

Extend
Retract

Double Acting

Types of Double-Acting Hydraulic Cylinders

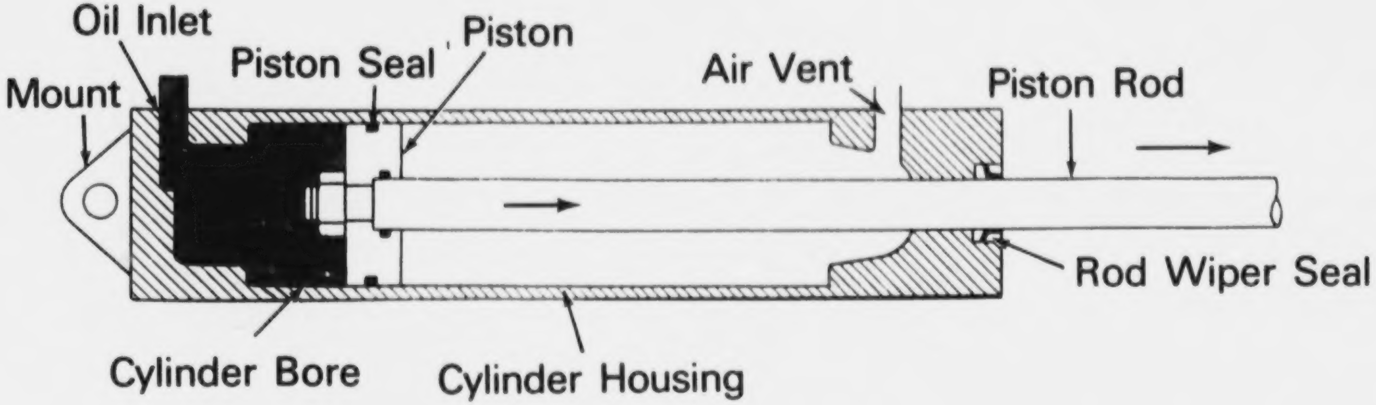


Unbalanced (Differential Type)

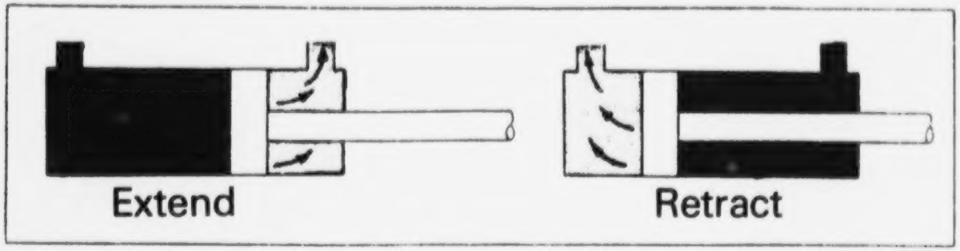


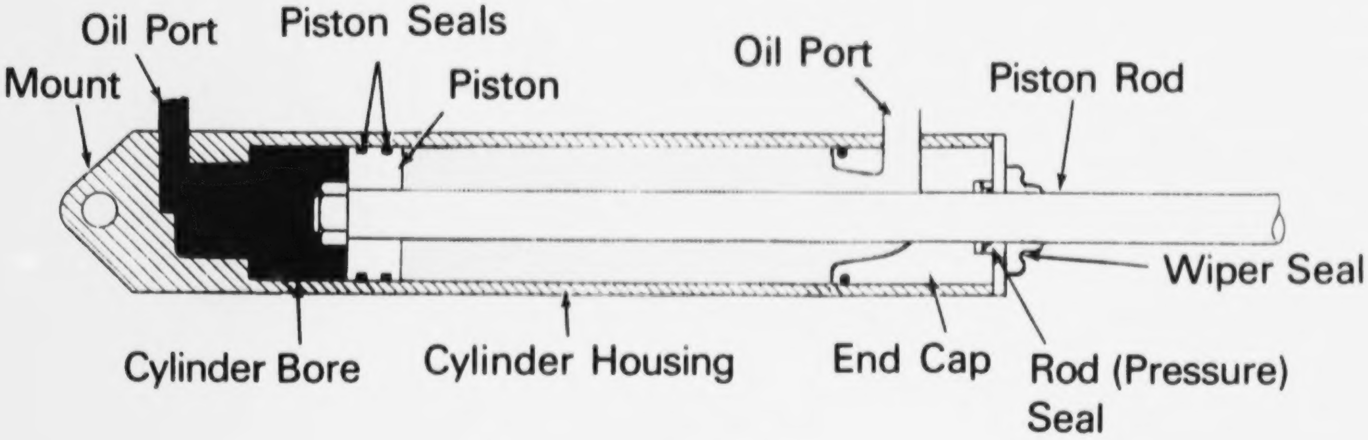
Balanced (Equal force both ways)

Single-Acting Cylinder


Oil Inlet
Piston Seal
Piston
Air Vent
Piston Rod
Mount
Rod Wiper Seal
Cylinder Bore
Cylinder Housing

Double-Acting Cylinder


Extend
Retract


Oil Port
Piston Seals
Mount
Piston
Oil Port
Piston Rod
Wiper Seal
Cylinder Bore
Cylinder Housing
End Cap
Rod (Pressure) Seal

CYLINDERS
UNIT IX

JOB SHEET #1 — DISASSEMBLE, INSPECT, AND REASSEMBLE A HYDRAULIC CYLINDER

A. Tools and materials

1. Wrenches of appropriate sizes
2. Cylinder
3. Replacement piston seal
4. Replacement rod seal
5. Replacement wiper seal

B. Routine #1 — Disassemble the cylinder

1. Use scribe to place match marks on end caps
2. Use appropriate wrenches to remove end cap
3. Remove rod assembly from cylinder barrel

☐ Have your instructor check your work

C. Routine #2 — Inspect the cylinder

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Examine cylinder barrel for scoring or abnormal wear		
2. Examine piston seal for nicking or uneven wear		
3. If the cylinder uses a piston seal, inspect for nicking or uneven wear		
4. If the cylinder uses a wiper seal, inspect for damage or nicking		
5. Examine the air vent or single-acting cylinders to insure the opening is not obstructed		

☐ Have your instructor check your work

JOB SHEET #1

D. Routine #3 — Reassemble the cylinder

1. Remove old piston seal
2. Carefully install a new piston seal onto the piston
3. Carefully insert rod assembly into the cylinder barrel
4. Install a new rod seal (if used)
5. Make sure orientation is correct (lip is out) and that seal is square to the rod
6. Install end cap
7. Align match marks
8. Tighten the bolts evenly on cylinders using the rods

☐ Have your instructor check your work

9. Clean up area and return tools and materials to proper storage

CYLINDERS
UNIT IX

JOB SHEET #2 — TEST A CYLINDER FOR INTERNAL AND EXTERNAL LEAKAGE

A. Tools and materials

1. Wrenches as required
2. Cylinder test fixture capable of holding a pressurized cylinder
3. Double-acting cylinder
4. Safety glasses

B. Routine #1 — Test for external leakage

1. With cylinder installed on machine or test fixture, apply pressure and visually inspect for leakage around the rod at the end cap
2. Repeat for several different positions

☐ Have your instructor check your work

C. Routine #2 — Test a double-acting cylinder for internal leakage

1. Install cylinder on test fixture, leaving the line to one side of the cylinder unconnected

   (NOTE: Only one side of the cylinder will be pressurized at a time.)

2. Bleed air from the side of the cylinder which will be pressurized
3. Apply pressure
4. Observe open outlet for any leakage flow
5. Repeat for several cylinder extensions
6. Remove pressure
7. Disconnect line to cylinder and reconnect to other side
8. Repeat steps 2 to 6 for other side of cylinder

☐ Have your instructor check your work

9. Clean up area and return tools and materials to proper storage

CYLINDERS
UNIT IX

NAME ____________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Area of the piston rod

_____b. Area of the cylinder piston

_____c. Effective area on the rod side of the cylinder; equal to the piston area minus the rod area

_____d. An actuator which converts hydraulic power into linear mechanical force and motion

_____e. Pressure in the return lines caused by flow in these lines

1. Piston area
2. Back pressure
3. Rod area
4. Rod side area
5. Cylinder

2. Discuss the operation of a hydraulic cylinder.

____

____

____

3. Distinguish between the operation of single-acting and double-acting cylinders by placing an "X" next to the descriptions of single acting cylinders.

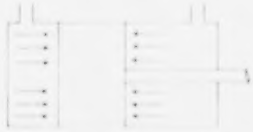
_____a. Oil flows into only one side of the cylinder

_____b. The cylinder is retracted by oil flow into the other side of the cylinder

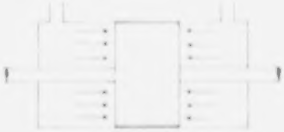
_____c. The cylinder is retracted by gravity or a spring

_____d. Oil flows into one side to extend the cylinder

4. Identify types of double-acting cylinders.



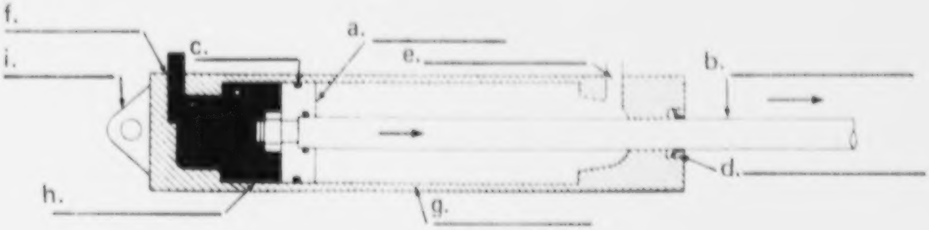
a. ______________________________



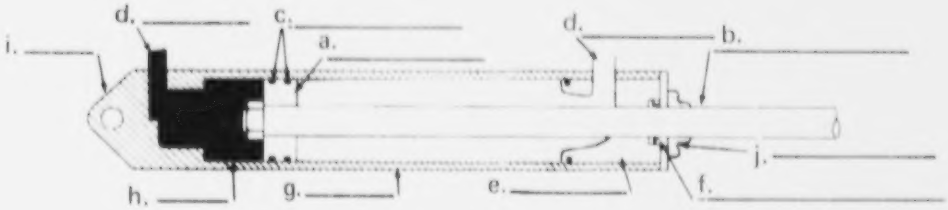
b. ______________________________

TEST

5. Identify the parts of a single-acting cylinder.



6. Identify the parts of a double-acting cylinder.


d.
c.
a.
i.
d.
b.
j.
h.
g.
e.
f.

7. List five sources of common failures of hydraulic cylinders.

a.

b.

c.

d.

e.

TEST

8. Calculate the force output in the following problems.

   a. Using the formula for single-acting force, F = PA, calculate the force if P = 2000 PSI and D = 4.00 inches

   b. Using the formula for double-acting force, Piston area × Piston pressure, and Rod side area × Rod side pressure, calculate the force when

      Piston pressure = 2000 PSI
      Rod diameter = 3.0 inches
      Piston diameter = 4.00 inches
      Rod-side pressure = 500 PSI

9. Calculate the speed of hydraulic cylinders in the following problems.

   a. Using the formula for single-acting rod speed, $\frac{\text{flow rate} \times 19.25}{\text{Piston area}}$ calculate rod speed when

      Flow rate into cylinder = Q = 10 GPM
      Piston diameter = P = 4 inches
      Constant = 19.25

   b. Using the formula for double-acting rod speed, $\frac{\text{flow rate} \times 19.25}{\text{Area}}$ calculate the retracting and extending speed when

      Piston diameter = 3 inches
      Rod diameter = 2 inches
      Piston area = 7.07 sq. in.
      Rod area = 3.14 sq. in.
      Rod side area = 3.93 sq. in.
      Flow rate = 10 GPM

      1) Retracting speed ______________________________

      2) Extending speed ______________________________

TEST

10. Using the formula for power output of a cylinder, $\frac{V \times F}{33{,}000}$, calculate the power output of a cylinder, when

    V = Rod velocity = 20 ft/sec
    F = Rod force = 10,000 pounds force
    Constant = 33,000

11. Using the formula for the flow rate required to move a cylinder a given distance in a given time, $Q = \frac{A \times L}{T \times 231}$, calculate the flow rate required to move a 2 inch diameter cylinder 10 inches in one minute.

12. Draw the symbol for a cylinder.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

13. Demonstrate the ability to:

    a. Disassemble, inspect, and reassemble a hydraulic cylinder.

    b. Test a cylinder for internal and external leakage.

CYLINDERS
UNIT IX

ANSWERS TO TEST

1. a. 3
   b. 1
   c. 4
   d. 5
   e. 2

2. Discussion should include:
   a. Hydraulic oil flows into a chamber of the cylinder, causing the cylinder rod to move
   b. Pressure of the fluid acting on the surface of a piston creates a force on the rod

3. a, c

4. a. Unbalanced
   b. Balanced

5. a. Piston
   b. Piston rod
   c. Piston seal
   d. Rod wiper seal
   e. Air vent
   f. Oil inlet
   g. Cylinder housing
   h. Cylinder bore
   i. Mount

6. a. Piston
   b. Piston rod
   c. Piston seals
   d. Oil ports
   e. End cap
   f. Rod seal
   g. Cylinder housing
   h. Cylinder bore
   i. Mount
   j. Wiper seal

7. Any five of the following:
   a. Bent rod
   b. Scored cylinder barrel
   c. Nicked or damaged rod
   d. Leaking piston seal
   e. Leaking rod seal
   f. Defective wiper seal

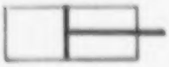
ANSWERS TO TEST

8.
   a. 25,120 lbs.
   b. 22,157.5 lbs.

9.
   a. 15.33 ft/min
   b.
      1) 48.98 ft/min
      2) 15.33

10. 6.06 HP

11. .136 GPM

12. 

13. Performance skills evaluated to the satisfaction of the instructor

MOTORS
UNIT X

UNIT OBJECTIVE

After completion of this unit, the student should be able to calculate hydraulic motor load torque, displacement, speed, inlet pressure, power, and efficiency. The student should also be able to select true statements concerning the operation of a gear motor, a vane motor, an an in-line axial piston motor. The student should also be able to disassemble, inspect, and reassemble a gear motor. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to motors with their correct definitions.
2. Name three kinds of hydraulic motors.
3. Given a formula, calculate hydraulic motor load torque.
4. Given a formula, calculate the displacement of a hydraulic motor.
5. Given a formula, calculate the speed of a hydraulic motor.
6. Given a formula, calculate hydraulic motor inlet pressure.
7. Given a formula, calculate hydraulic motor input and output power.
8. Given a formula, calculate motor overall efficiency.
9. Select true statements concerning the operation of a gear motor.
10. Select true statements concerning the operation of an unbalanced vane motor.
11. Name three types of piston motors.
12. Select true statements concerning the operation of an in-line axial piston motor.
13. Demonstrate the ability to disassemble, inspect, and reassemble a gear motor. (Job Sheet #1)

MOTORS
UNIT X

SUGGESTED ACTIVITIES

A. Provide students with objective sheet.

B. Provide students with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheet.

G. Show students examples of vane, gear, and piston motors.

H. Give test.

CONTENTS OF THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

  1. TM 1 — Motor Load Torque

  2. TM 2 — Operation of a Gear and Vane Motor

  3. TM 3 — Operation of an In-Line Axial Piston Motor

D. Job Sheet #1 — Disassemble, Inspect, and Reassemble a Gear Motor

E. Test

F. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Fundamentals of Service, Hydraulics.* Moline, IL: Deere and Company, 1967.

B. *Fluid Power 1.* Cleveland, OH 44112: Parker-Hannifin Corporation, 1975.

MOTORS
UNIT X

INFORMATION SHEET

I. **Terms and definitions**

A. Hydraulic motor — A device for converting fluid energy into mechanical force and motion

B. Torque — A measure of rotational (twisting) load or effort; calculated as force times distance

C. Displacement — The volume of fluid which is transported from the motor inlet to the outlet during one revolution of the motor

D. Efficiency — The output power divided by the input power

E. Foot-pound — A unit of torque equal to 12 inch-pounds

(NOTE: Foot-pounds are abbreviated ft-lbs.)

F. Back pressure — Pressure at the outlet of a motor caused by pressure drop in the return lines

II. **Kinds of hydraulic motors**

A. Gear

B. Vane

C. Piston

(NOTE: These are positive displacement motors. Nonpositive displacement motors do exist but are not commonly used in hydraulic systems.)

III. **Formula for calculation of hydraulic motor load torque** (Transparency 1) — Torque = Distance × Force

Where Torque is expressed in ft-pounds or inch-pounds
Force = Load force expressed in pounds
Distance = Distance from center of shaft to line of action of applied force, measured perpendicular to line of action and expressed in units of inches or feet

Example: If a 100 pound force is applied to the shaft of a hydraulic motor one foot from the center of the shaft, then the output torque is 100 ft-pounds
Torque = Distance × Force
Torque = (1 ft) (100 pounds) = 100 ft-pounds

INFORMATION SHEET

IV. **Formula for calculating the displacement of a hydraulic motor** — $d = \frac{231\ Q}{n}$

Where d = Displacement in units of cubic inches per revolution ($in.^3/rev$)
Q = Motor inlet flowrate in units of gallons per minute (GPM)
n = Shaft speed in units of revolutions per minute (RPM)

Example: The displacement of a motor which has a shaft speed of 1800 RPM

when the inlet flowrate is 20 GPM is 2.56 in^3/rev.

$$d = \frac{231 \times 20\ GPM}{1800\ RPM} = 2.56\ in^3/rev.$$

V. **Formula for calculating the speed of a hydraulic motor** — $n = \frac{Q \times 231}{d}$

Where n = Shaft speed in units of revolutions per minute (RPM)
Q = Motor inlet flowrate in units of gallons per minute (GPM)

d = Displacement in units of cubic inch per revolution ($in^3/rev.$)

Example: the speed of a 2.56 in^3/rev motor with an inlet flowrate of 25 GPM is 2255 RPM

$$m = \frac{(25\ GPM) \times 231}{2.56\ in^3/rev} = 2255\ RPM$$

VI. **Formula for calculating hydraulic motor inlet pressure** —

$$P = \frac{Torque \times 2\pi}{d} \qquad (\pi = 3.14)$$

Where P = Inlet pressure in units of pounds per square inch (PSI)
Torque = Shaft torque in units of inch-pounds (in-lbs.)

d = Displacement in cubic inches per revolution (in^3/rev)

Example: A hydraulic motor has a displacement of 2.56 cubic inches per revolution. The load torque is 700 in-lbs. The inlet pressure is 1717 PSI.

$$P = \frac{(700\ in\text{-}lbs.) \times 6.28}{2.56} = 1700$$

INFORMATION SHEET

VII. Formula for calculating hydraulic motor power

A. Input power — $\text{Power} = \dfrac{P \times Q}{1714}$

Where Power = Input in units of horsepower (HP)
P = Inlet pressure in units of PSI
Q = Inlet flowrate in units of GPM

Example: The input power of a hydraulic motor operating at 20 GPM inlet flow and 3000 PSI inlet pressure is 35 HP

$$\text{Power} = \frac{3000\ \text{PSI} \times 20\ \text{GPM}}{1714} = 35\ \text{HP}$$

B. Output power — $\text{Power} = \dfrac{n \times \text{Torque}}{5252}$

Where Power = Output power in units of horsepower (HP)
n = Shaft speed in units of revolutions per minute (RPM)
Torque = Output torque in units of foot-pounds (ft-lbs.)

Example: The output power of a hydraulic motor operated at 2400 RPM with an output load of 70 ft-lbs. is 32 HP

$$\text{Power} = \frac{(2400\ \text{RPM})\ (70\ \text{ft-lbs.})}{5252} = 32\ \text{HP}$$

VIII. Formula for the calculation of motor overall efficiency —

$$\text{Eff} = \frac{\text{Output power}}{\text{Input power}}$$

Example: A motor is operated at the output powr of 27 HP. The input power required is 32 HP. The efficiency is 0.844.

$\text{Eff} = {}^{27}/_{32} = 0.844$; Therefore the motor is 84.4% efficient.

IX. Operation of a gear motor (Transparency 2)

A. Pressurized hydraulic fluid is supplied to the inlet of the motor

B. The pressure creates a force on the face of each gear tooth

C. The pressure force on the gear teeth is balanced; a force on one face which would tend to cause rotation in the clockwise direction is balanced by a force on an adjacent face which would tend to cause rotation in the opposite direction

INFORMATION SHEET

D. This balancing of forces exist at all gear teeth except where the teeth just begin to unmesh

E. At this location, the forces are not balanced which tends to cause the motor to rotate

F. As the motor rotates, small volumes of fluid are trapped between the gear teeth and are carried to the outlet

G. The fluid at the outlet is expelled at a lower pressure

(NOTE: The operation of an external gear motor has been discussed. Other types of gear motors do exist.)

X. **The operation of an unbalanced vane motor** (Transparency 2)

A. A vane motor consists of a ring, vanes, rotor, shaft, and a port plate with kidney shaped inlet and outlet ports

B. The rotor is installed off-centered in the ring

C. The vanes are installed into the rotor and are free to move radially

D. The vanes are spring-loaded to force the vanes to contact the surface of the ring

(NOTE: Hydraulic pressure may be used to force the rotors against the ring.)

E. Pressurized hydraulic fluid is supplied to the inlet of the motor

F. Because the rotor is installed off center, an imbalance on the vanes is created which tends to cause the rotor and motor shaft to turn

G. As the rotor turns a small volume of fluid is trapped and carried to the outlet and expelled at a lower pressure

(NOTE: Some vane motors are designed to balance the load on the shaft bearing by having two inlet and two outlet ports. The inlet ports are positioned directly opposite each other. This design is called a balanced vane motor.)

XI. **Types of piston motors**

A. Radial

B. In-line axial

C. Bent axis axial

INFORMATION SHEET

XII. **Operation of an in-line axial piston motor** (Transparency 3)

A. The motor consists of a swash plate, pistons with shoes, a cylinder barrel, shaft, and port plate

B. The pistons are installed in the cylinder barrel and are connected with the swash plate

C. The swash plate is positioned at an angle thus causing the pistons to extend into the cylinder block a varying amount

D. Pressurized hydraulic fluid is supplied to the inlet of the motor, which causes a force to be applied to the top of a piston

E. This, in turn, causes the piston and shoe to slide on the swash plate from the high side to the low side causing the cylinder barrel and shaft to rotate (Transparency 5)

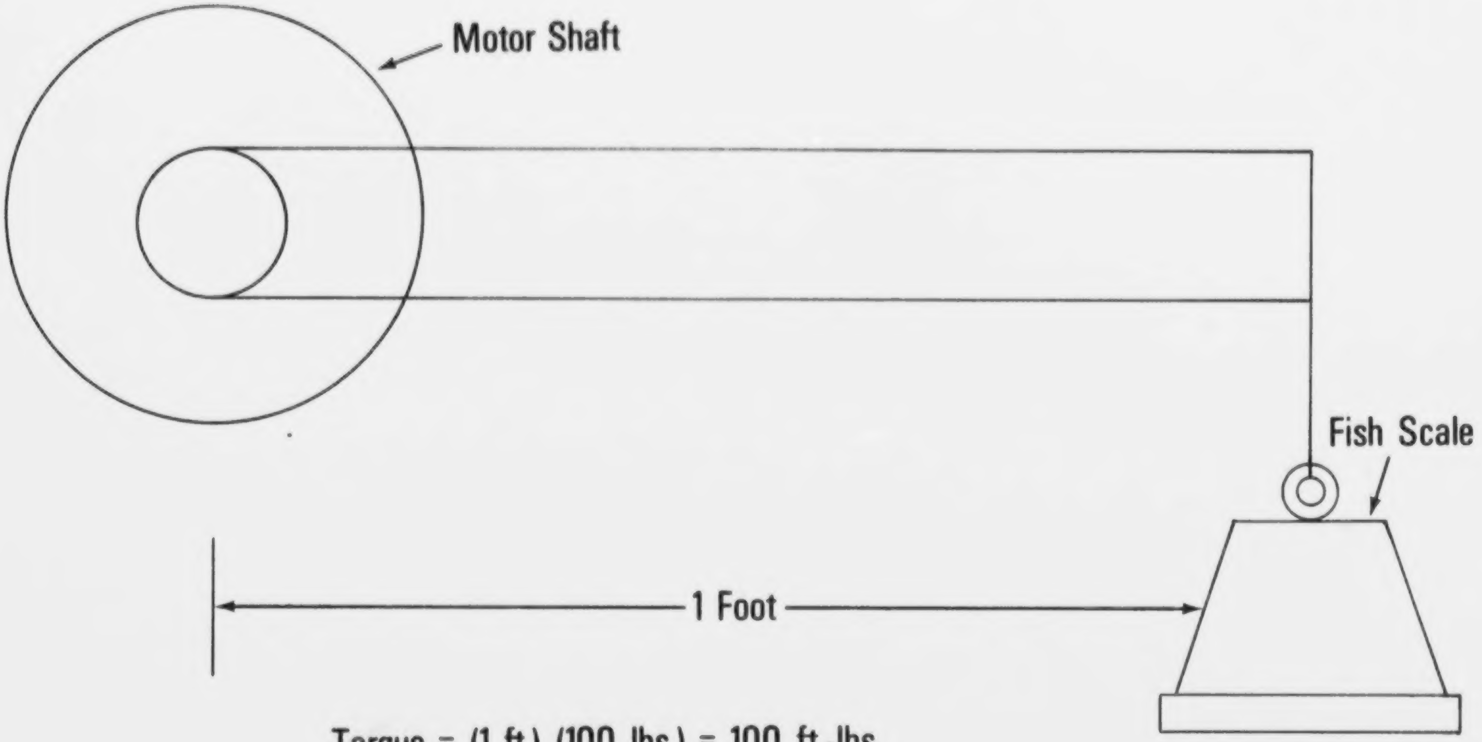
(NOTE: The swash plate does not rotate with the pistons, cylinder barrel and shaft.)

F. As each piston is forced to move, it rotates from the inlet to the outlet

G. In doing this it carries a small amount of fluid from the inlet to outlet

H. This fluid is expelled from the outlet at a lower pressure

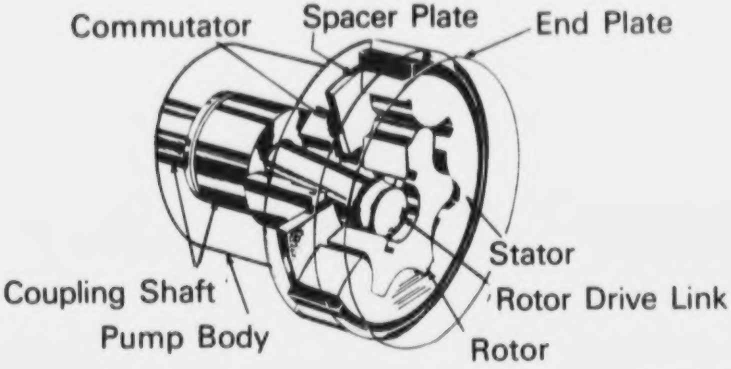
Motor Load Torque


Motor Shaft
Fish Scale
1 Foot

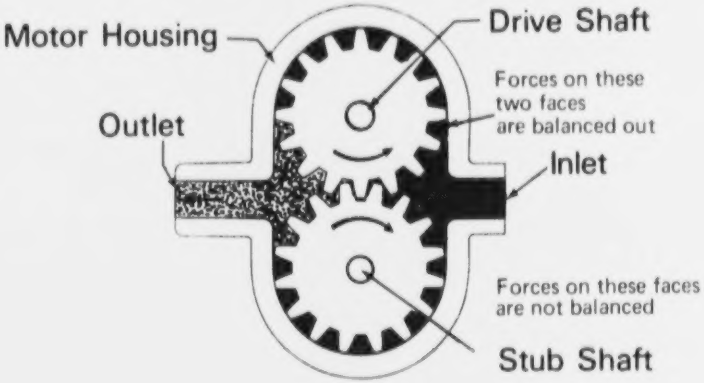
Torque = (1 ft.) (100 lbs.) = 100 ft.-lbs.

Operation of a Gear and Vane Motor

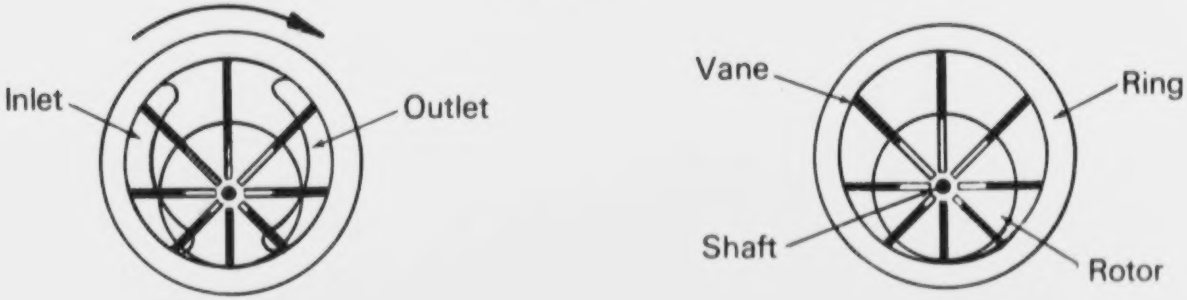
Internal Gear Motor


Commutator
Spacer Plate
End Plate
Stator
Rotor Drive Link
Coupling Shaft
Pump Body
Rotor

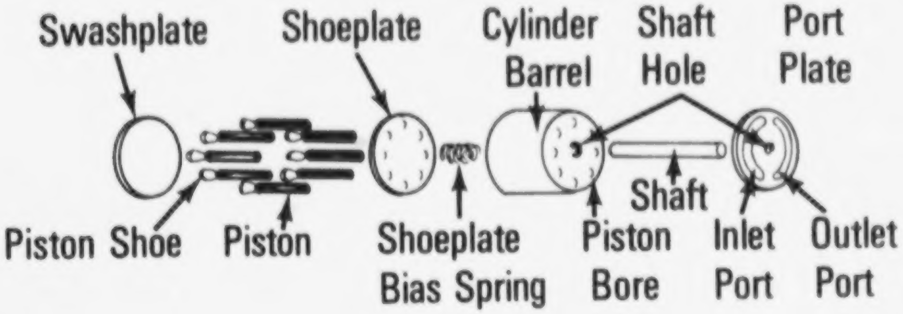
External Gear Pump in Operation

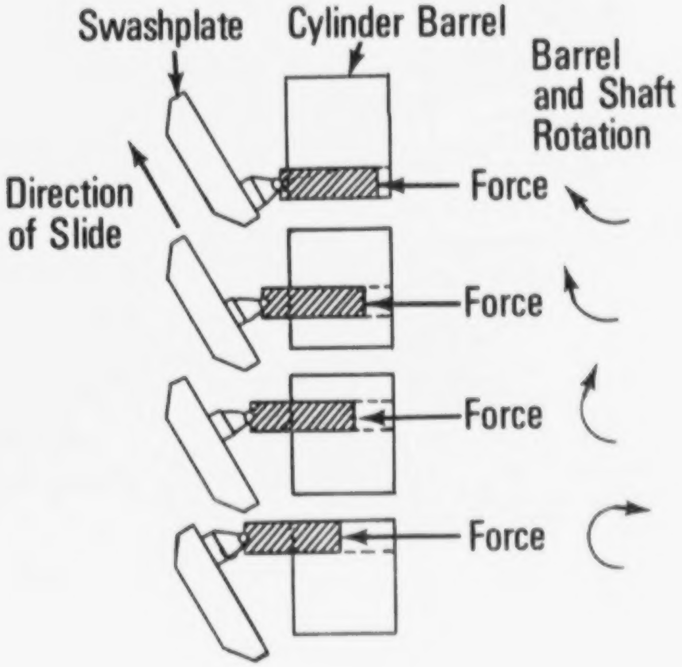

Motor Housing
Drive Shaft
Forces on these two faces are balanced out
Outlet
Inlet
Forces on these faces are not balanced
Stub Shaft

Vane Motor


Inlet
Outlet
Vane
Ring
Shaft
Rotor

Operation of an In-Line Axial Piston Motor


Swashplate
Shoeplate
Cylinder Barrel
Shaft Hole
Port Plate
Shaft
Piston Shoe
Piston
Shoeplate Bias Spring
Piston Bore
Inlet Port
Outlet Port


Swashplate
Cylinder Barrel
Barrel and Shaft Rotation
Direction of Slide
Force
Force
Force
Force

MOTORS
UNIT X

JOB SHEET #1 — DISASSEMBLE, INSPECT, AND REASSEMBLE A GEAR MOTOR

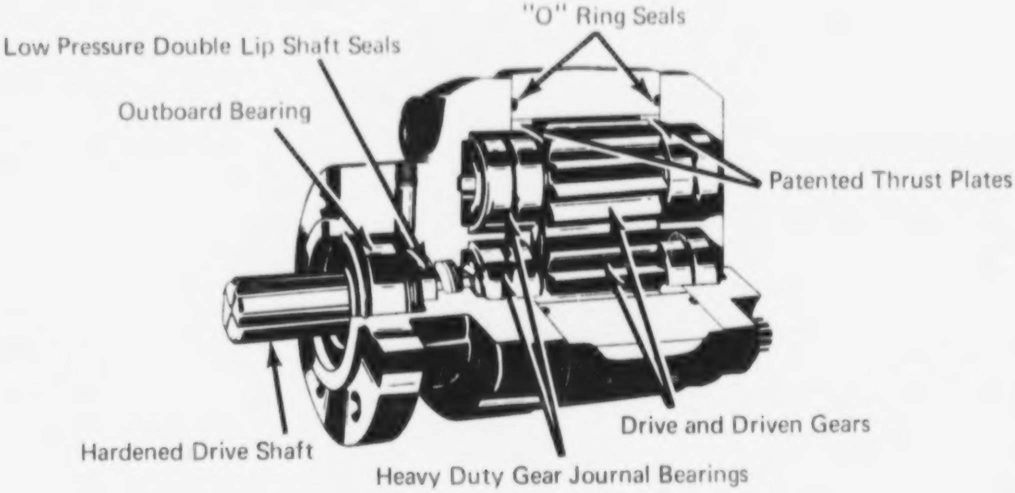
A. Tools and materials

1. Gear motor
2. Service manual for motor (if available)
3. Hand tool set
4. Solvent
5. Lint free shop towels
6. Safety glasses

B. Routine #1 — Disassemble the gear motor

(NOTE: Figure 1 shows a cut-away drawing of a typical gear motor with an outboard bearing on the motor shaft. Figure 2 is an exploded view of this motor.)

FIGURE 1


"O" Ring Seals
Low Pressure Double Lip Shaft Seals
Outboard Bearing
Patented Thrust Plates
Drive and Driven Gears
Hardened Drive Shaft
Heavy Duty Gear Journal Bearings

JOB SHEET #1

FIGURE 2

1A	Snap Ring
1B	Outboard Bearing
1	Double Lip Seal
2	Shaft End Cover
3	Shaft Seals
4	Check Assemblies
5	Roller Bearings
6	Thrust Plates
7	Pocket Seals
8	Integral Shaft and Gear Set
9	Gasket Seals
10	Gear Housing
11	Port End Cover
12	Washers
13	Cap Screws

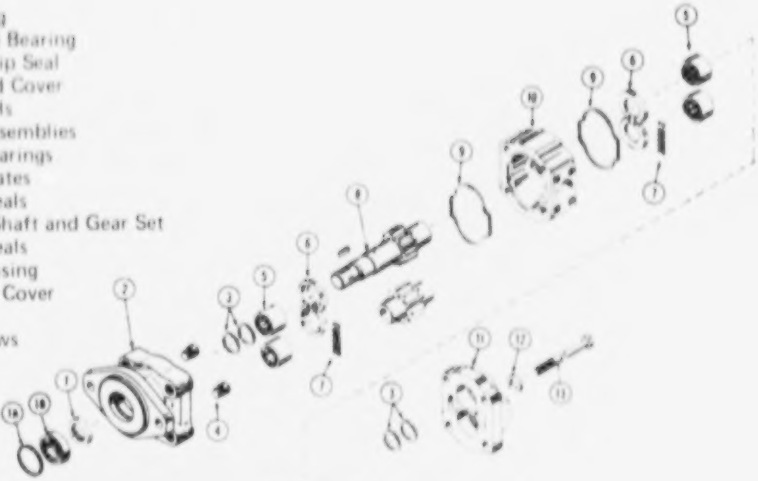


FIGURE 2

1. Thoroughly clean the external surfaces of the motor with solvent and dry the motor with shop towels
2. Place the motor on a clean surface for disassembly
3. Remove the clip ring retainer on the outboard shaft bearing (if used)
4. Remove the bearing
5. Remove the four cap screws which hold the motor housing together
6. Slowly remove the port (rear) end cover from the motor
7. Remove the two port side roller bearings from the assembly
8. Remove the rear thrust plate, noting orientation of the plate
9. Remove the gear housing from the motor
10. Carefully remove the two gears from the motor
11. Remove the shaft side thrust plate, noting orientation of plate
12. Remove the two shaft side roller bearings
13. Remove shaft seal

☐ Have your instructor check your work

JOB SHEET #1

C. Routine #2 — Inspect the gear motor

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Examine the two thrust plates for excessive wear or condition scoring		
2. Examine the gears for excessive wear and broken teeth		
3. Examine the roller bearings for excessive wear and fractured bearings		
4. Examine the shaft seal for scoring		
5. Examine the gear housing seals (usually O-rings) for nicks or breaks		
6. Replace any part found to be defective		

☐ Have your instructor check your work

D. Routine #3 — Reassemble the gear motor

(NOTE: Pre-lube parts during assembly.)

1. Carefully install the shaft seal
2. Install the two shaft-side roller bearings
3. Install the shaft side thrust plate
4. Install the two gears into the shaft end cover
5. Insure that the two seals on the gear housing are properly installed and then lower the gear housing around the two gears and align with the shaft end cover
6. Install the port side thrust plate
7. Install the port side roller bearings
8. Install the port side end cover onto the assembly and carefully align
9. Install the four cap screws

JOB SHEET #1

10. Uniformly torque the screws by alternately applying torque to screws on opposite sides of the motor

11. Reinstall the shaft outboard bearing and clip ring

12. Fill motor with fluid as specified by the manufacturer before operation

☐ Have your instructor check your work

13. Clean up area and return tools and materials to proper storage

MOTORS
UNIT X

NAME ________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. A measure of rotational load or effort; calculated as force times distance

_____b. The output power divided by the input power

_____c. The volume of fluid which is transported from the motor inlet to the outlet duringone revolution of the motor

_____d. A device for converting fluid energy into mechanical force and motion

_____e. A unit of torque equal to 12 inch-pounds

_____f. Pressure at the outlet of a motor caused by pressure drop in the return lines

1. Back pressure
2. Hydraulic motor
3. Displacement
4. Torque
5. Efficiency
6. Foot-pound

2. Name three kinds of hydraulic motors.

a. ____

b. ____

c. ____

3. Using the formula for torque, calculate hydraulic motor load torque if a 150 pound force is applied to the shaft of a hydraulic motor two feet from the center of the shaft.

Torque = Distance × Force

TEST

4. Using the formula for displacement, calculate the displacement of a motor which has a shaft speed of 1750 RPM when the inlet flowrate is 22 GPM.

$$d = \frac{231\ Q}{n}$$

5. Using the formula for speed, calculate the speed of a 2.56 in^3/rev. hydraulic motor with an inlet flowrate of 24 GPM.

$$n = \frac{Q \times 231}{d}$$

6. Using the formula for inlet pressure, calculate inlet pressure of a hydraulic motor which has a displacement of 2.56 cubic inches per revolution and a load torque of 750 in-lbs.

$$P = \frac{\text{Torque} \times 2\pi}{d}$$

7. a. Using the formula for input power, calculate the input power of a motor operating at 21 GPM inlet flow and 2500 PSI inlet pressure.

$$\text{Power} = \frac{P \times Q}{1714}$$

   b. Using the formula for output power, calculate the output power of a motor which is operating at 2000 RPM with an output load of 50 ft-lbs.

$$\text{Power} = \frac{n \times \text{Torque}}{5252}$$

TEST

8. Using the formula $\text{Eff} = \frac{\text{Output power}}{\text{Input power}}$, calculate the motor overall efficiency if the output power is 25 HP and the input power is 30 HP.

9. Select true statements concerning the operation of a gear motor by placing an "X" in the appropriate blanks.

_____a. Pressurized hydraulic fluid is supplied to the inlet of the motor

_____b. The pressure creates a force on the face of each gear tooth

_____c. The pressure force on the gear teeth is balanced; a force on one face which would tend to cause rotation in the clockwise direction is balanced by a force on an adjacent face which would tend to cause rotation in the opposite direction

_____d. This balancing of forces exist at all gear teeth except where the teeth just begin to unmesh

_____e. At this location, the forces are not balanced which tends to cause the motor to rotate

_____f. As the motor rotates, small volumes of fluid are trapped between the gear teeth and are carried to the outlet

_____g. The fluid at the outlet is expelled at a much higher pressure

10. Select true statements concerning the operation of an unbalanced vane motor by placing an "X" in the appropriate blanks.

_____a. A vane motor consists of a ring, vanes, rotor, shaft, and a port plate with kidney shaped inlet and outlet ports

_____b. The rotor is installed in the center of the ring

_____c. The vanes are installed into the port plate and cannot move

_____d. The vanes are spring-loaded to force the vanes to contact the surface of the ring

_____e. Pressurized hydraulic fluid is supplied to the inlet of the motor

_____f. At this point the vanes are balanced and the rotor turns

_____g. As the rotor turns a small volume of fluid is trapped and carried to the outlet and expelled at a lower pressure

TEST

11. Name three types of piston motors.

a. ______________________________

b. ______________________________

c. ______________________________

12. Select true statements concerning the operation of an in-line axial piston motor by placing an "X" in the appropriate blanks.

_____a. The motor consists of a swash plate, pistons with shoes, a cylinder barrel, shaft, and port plate

_____b. The swash plate is positioned at an angle thus causing the pistons to extend into the cylinder block a varying amount

_____c. Pressurized hydraulic fluid is supplied to the inlet of the motor, which causes a force to be applied to the shaft

_____d. This, in turn, causes the piston and shoe to slide on the swash plate from the high side to the low side, causing the cylinder barrel and shaft to rotate

_____e. As each piston is forced to move, it rotates from the outlet to the inlet

_____f. In doing this it carries a small amount of fluid from the inlet to the outlet

_____g. This fluid is expelled from the outlet at a lower pressure

(NOTE: If the following activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

13. Demonstrate the ability to disassemble, inspect, and reassemble a gear motor.

MOTORS
UNIT X

ANSWERS TO TEST

1. a. 4 c. 3 e. 6
   b. 5 d. 2 f. 1

2. a. Gear
   b. Vane
   c. Piston

3. 300 ft-lbs.

4. 2.9 in^3/rev.

5. 2165 RPM

6. 1840 PSI

7. a. 30.6 HP
   b. 19 HP

8. 83%

9. a, b. c, d, e, f

10. a, d, e, g

11. a. Radial
    b. In-line axial
    c. Bent axis axial

12. a, b, d, f, g

13. Performance skill evaluated to the satisfaction of the instructor

ACCESSORIES
UNIT XI

UNIT OBJECTIVE

After completion of this unit, the student should be able to list safety precautions for working with accumulators and explain reasons for using a cooler and a heater. The student should also be able to inspect, clean, and test a cooler and a heater. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Define terms associated with accessories.
2. Select functions of an accumulator.
3. Identify types of accumulators.
4. Identify types of gas-loaded accumulators.
5. List safety precautions for working with accumulators.
6. Explain reasons for using a cooler.
7. Describe types of coolers.
8. Match components of an air-cooled cooler with their functions.
9. List common failures of coolers.
10. Explain reasons for using a heater.
11. Describe two types of heaters.
12. List two common failures of heaters.
13. Demonstrate the ability to:
    a. Inspect, clean, and test an air-cooled cooler. (Job Sheet #1)
    b. Inspect, clean, and test a heater. (Job Sheet #2)

ACCESSORIES
UNIT XI

SUGGESTED ACTIVITIES

A. Provide students with objective sheet.

B. Provide students with information and job sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Demonstrate how to recharge an accumulator according to manufacturer's specifications.

H. Give test.

CONTENTS OF THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency macters

  1. TM 1 — Types of Accumulators
  2. TM 2 — Types of Gas-Loaded Accumulators
  3. TM 3 — Air-Cooled Cooler
  4. TM 4 — Water-Cooled Cooler

D. Job sheets

  1. Job Sheet #1 — Inspect, Clean, and Test an Air-Cooled Cooler
  2. Job Sheet #2 — Inspect, Clean, and Test a Heater

E. Test

F. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Fundamentals of Service, Hydraulics.* Moline, IL: Deere and Company, 1967.

B. *Service Manual SM2039, John Deere 4000 Tractor.* Waterloo, IA: Deere and Company, 1967.

C. *Ford Tractor Repair Manual.* Troy, MI: Tractor Operations, Ford Motor Company, 1983.

ACCESSORIES
UNIT XI

INFORMATION SHEET

I. **Terms and definitions**

   A. Accumulator — A device for storing hydraulic energy

   B. Cooler — A device for removing heat from hydraulic fluids

   C. Heater — A device for adding heat to hydraulic fluids

   D. Thermostat — An automatic device for regulating temperature

II. **Functions of an accumulator**

   A. Stores energy

   B. Absorbs shock

   C. Allows the system to build pressure gradually

   D. Maintains pressure

III. **Types of accumulators** (Transparency 1)

   A. Gas-loaded (gas-charged)

   B. Weight-loaded

   C. Spring-loaded

IV. **Types of gas-loaded accumulators** (Transparency 2)

   A. Piston type

   B. Bladder type

   C. Diaphragm type

V. **Safety precautions for working with accumulators**

   (NOTE: Accumulators are used to store energy and therefore can pose severe safety hazards.)

   A. *Always* discharge stored hydraulic fluid from the accumulator prior to removing it from the system

      (NOTE: Valves, brake pedals, etc., should be operated to insure all stored hydraulic energy has been expelled. Failure to do this could result in severe injury from high pressure fluid escaping.)

INFORMATION SHEET

B. Never charge an accumulator to a pressure more than that recommended by the manufacturer

C. *Never* fill an accumulator with oxygen; an explosion could result if oil and oxygen mix

D. Only fill the accumulator with an inert gas such as dry nitrogen, because dry nitrogen is free of water vapor and oxygen

(NOTE: Allowing water vapor to enter the accumulator can cause the accumulator to rust.)

E. Do not use compressed air in an accumulator

F. Before disassembling an accumulator release both gas and hydraulic pressures

G. Use extreme care in removing the springs from spring-loaded accumulators

VI. **Reasons for using a cooler**

A. To prevent power losses (inefficiencies) in various hydraulic components such as pumps, valves, and lines

B. To prevent excessive operating temperatures

C. To remove heat from the hydraulic system and increase component life

VII. **Types of coolers** (Transparencies 3 and 4)

A. Air-cooled cooler — Uses moving air past a radiator to dissipate the heat

B. Water-cooled cooler — Uses water flowing through tubes immersed in the oil to remove the heat

VIII. **Components of an air-cooled cooler and their functions**

A. Top tank — Holds incoming hot hydraulic fluid

B. Core — A radiator-like device over which air passes to cool the hydraulic fluid

(NOTE: Air-cooled coolers must be located in front of the engine radiator to assure a steady supply of air.)

C. Bypass valve — Located between the top and bottom tanks to protect the cooler from excessive pressure build-up during cold weather starting, and dumps fluid into the main pump when a closed-center system is depleted of fluid

Example: Single-acting cylinder operation

D. Bottom tank — Holds cooled hydraulic fluid

INFORMATION SHEET

IX. **Common failures of coolers**

- A. Cooling fins on air-cooled models become clogged with dirt and debris
- B. Water tubes on water-cooled models become plugged with sediment
- C. Water leaks into fluid
- D. Fluid leaks into water

X. **Reasons for using a heater**

- A. The viscosity of hydraulic fluid is sensitive to temperature; at cold temperatures the fluid is thick and large pressure losses can occur in the lines
- B. In cold environments heaters are often used to help raise the temperature to the desired operating temperature or to help maintain the desired operating temperature

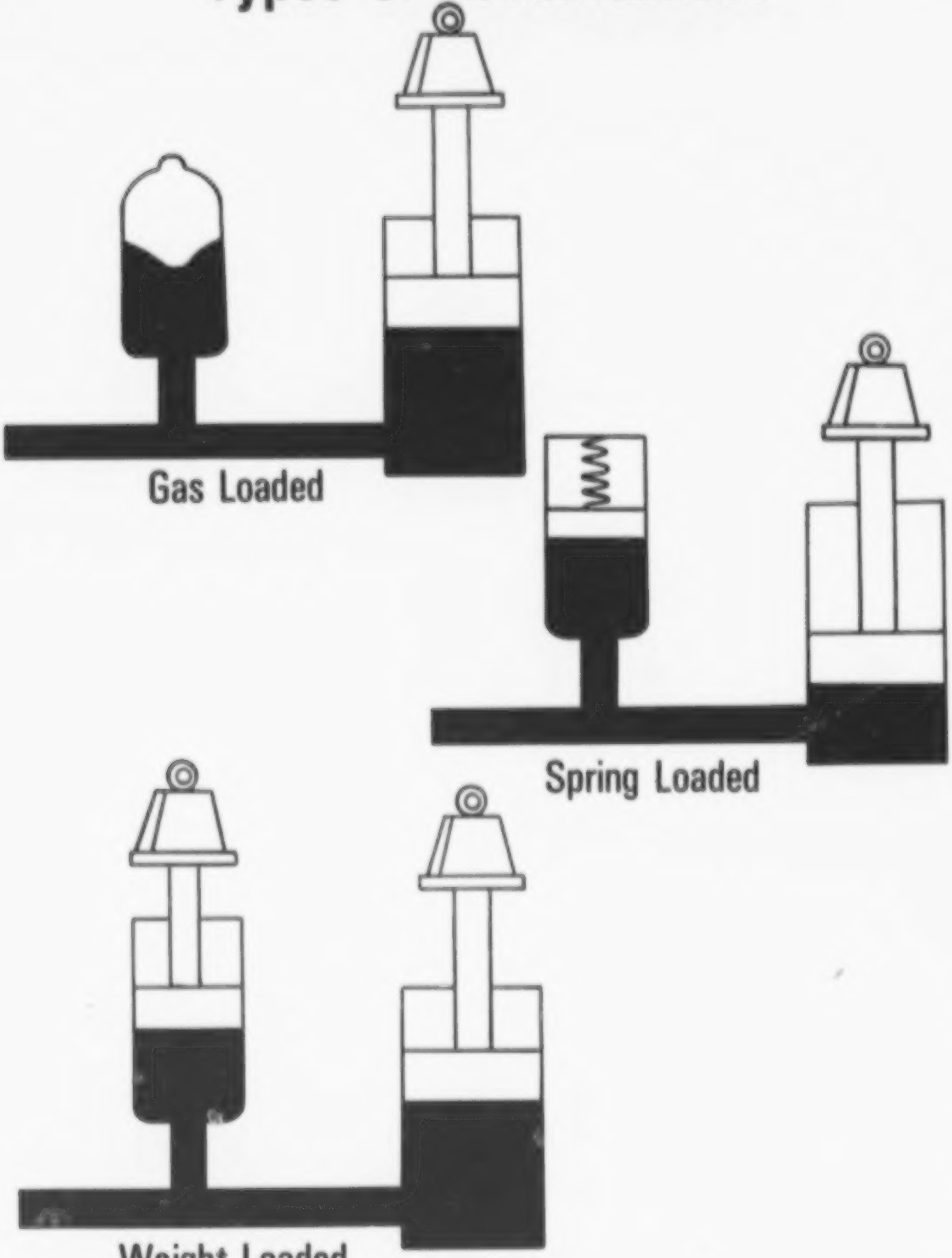
XI. **Types of heaters**

- A. Electric — Uses electric heating element to add heat to the system
- B. Heat exchangers — Uses the same principle as a cooler, except instead of removing heat, hot air or liquid is used to add heat

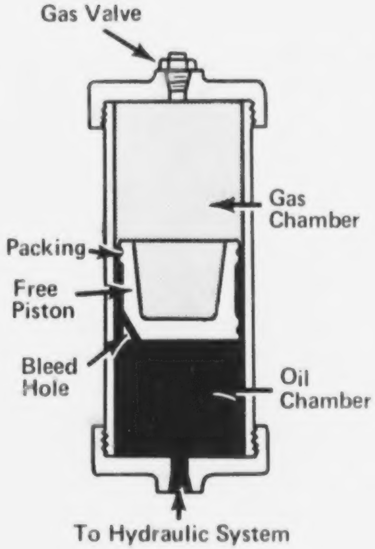
XII. **Common failures of heaters**

- A. Electrical heating element fails
- B. Heat exchanger fails (see above)

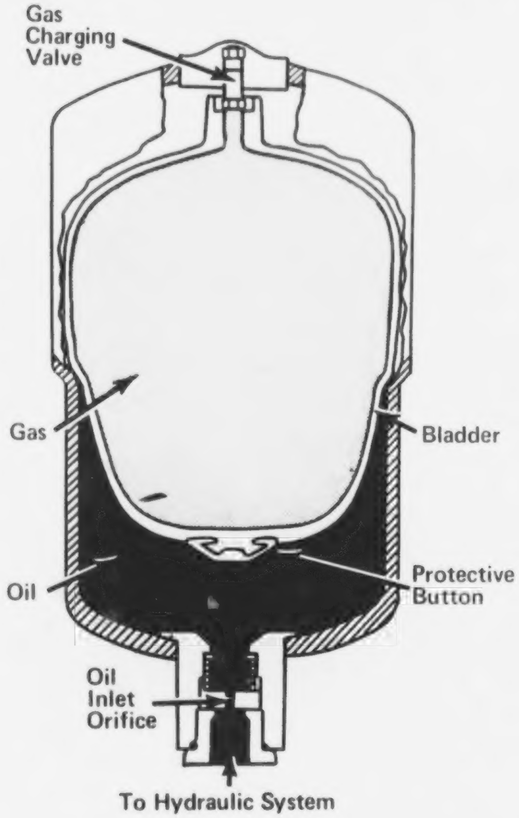
Types of Accumulators


Gas Loaded
Spring Loaded
Weight Loaded

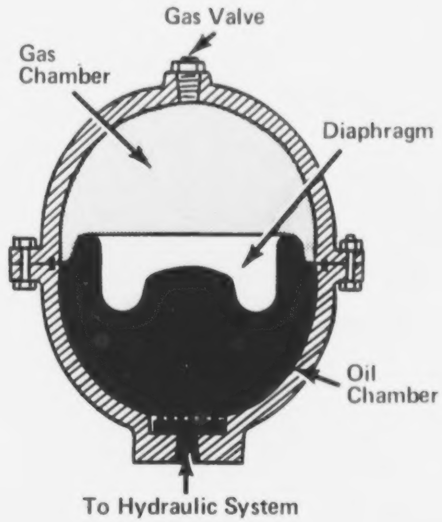
Types of Gas-Loaded Accumulators


Gas Valve
Gas Chamber
Packing
Free Piston
Bleed Hole
Oil Chamber
To Hydraulic System

Piston-Type Accumulator

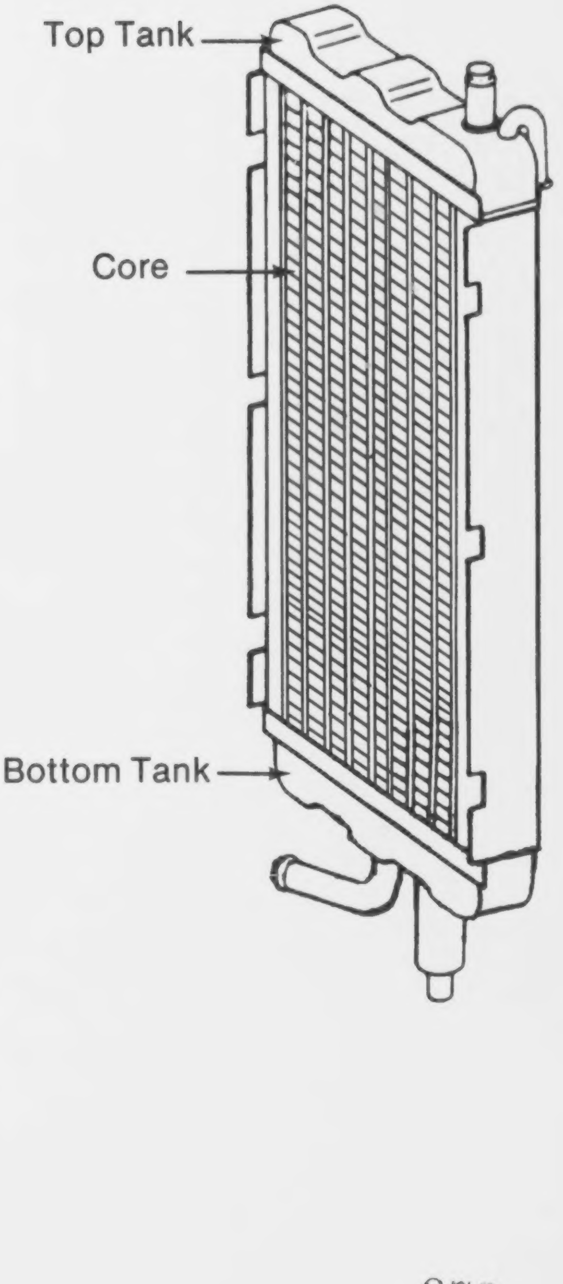

Gas Charging Valve
Gas
Bladder
Oil
Protective Button
Oil Inlet Orifice
To Hydraulic System

Bladder-Type Accumulator in Operation

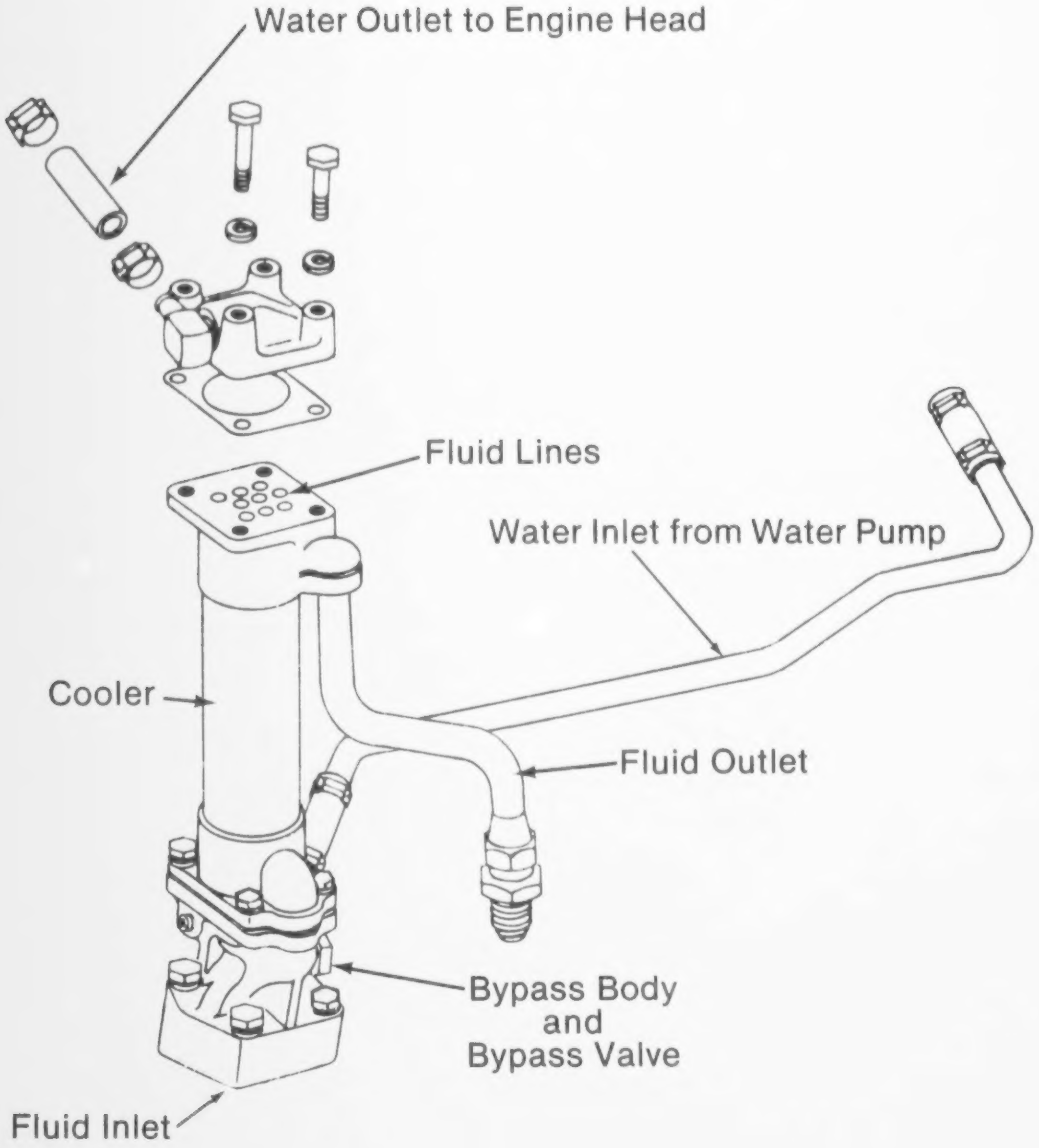

Gas Valve
Gas Chamber
Diaphragm
Oil Chamber
To Hydraulic System

Diaphragm-Type Accumulator

Air-Cooled Cooler


Top Tank
Core
Bottom Tank

Water-Cooled Cooler


Water Outlet to Engine Head
Fluid Lines
Water Inlet from Water Pump
Cooler
Fluid Outlet
Bypass Body
and
Bypass Valve
Fluid Inlet

ACCESSORIES
UNIT XI

JOB SHEET #1 — INSPECT, CLEAN, AND TEST AN AIR-COOLED COOLER

A. Tools and materials

1. Air-cooled cooler
2. Hand tool set
3. Service manual, if available
4. Solvent
5. Lint free shop towels
6. Safety glasses
7. Caps for covering fluid ports
8. Hydraulic power supply capable of providing hydraulic fluid at the rated pressure and flow capacity of the cooler

   (NOTE: The power supply should have a load valve in the return line.)
9. Pressurized air supply
10. Water tank

B. Routine #1 — Clean the cooler

1. Install caps to cover the fluid ports
2. Remove any caked-on dirt and mud from outside of the cooler
3. Use solvent to remove any residual grease or films from external surfaces
4. Allow solvent to dry
5. Remove the caps on the fluid ports
6. Flush the unit with solvent

☐ Have your instructor check your work

JOB SHEET #1

C. Routine #2 — Inspect the cooler

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Examine external welds and joints for any signs of cracking		
2. Examine fins for damage		
3. Examine the fittings for damage		

☐ Have your instructor check your work

D. Routine #3 — Inspect the cooler

1. Connect the cooler to the hydraulic power supply
2. Slowly increase the pressure on the inlet side of the cooler until rated pressure is attained by slowly closing the load valve
3. Examine the cooler for leaks, paying close attention to the area near weld, joints and fluid fittings
4. Note any leaks
5. Open the load valve
6. Supply the cooler with fluid flow at flow rate equal to its rated capacity
7. Allow the fluid to circulate until operating temperature is reached
8. Measure the differential pressure across the cooler with rated flow rate
9. Record and compare to manufacturer's specifications

   (NOTE: Excessive differential pressure is an indication of internal blockage. If pressure is too great examine internal surfaces for blockage.)

☐ Have your instructor check your work

JOB SHEET #1

E. Routine #4 — Inspect the cooler with alternate inspection routine

(NOTE: In situations where a hydraulic power supply is not present, this routine can be used to effectively inspect a cooler.)

1. Remove the cooler from the system
2. Drain all hydraulic fluid from the system
3. Plug the outlet of the bottom tank with a short piece of hose with a pressure plug in it

   (NOTE: The plug must be capable of holding about 120 pounds of pressure.)

4. Submerge the cooler in a water tank
5. Connect the air supply to the inlet line of the top tank
6. Activate the air supply and watch the water for bubbles that indicate leaks in the system
7. Continue test until certain there are no leaks or until all leaks have been isolated
8. Repair leaks as required or replace cooler if damage is beyond repair

   (NOTE: Leaks in the fin-like cooling structure can be repaired at a radiator shop, and the core and both tanks can be repaired with either soldering or brazing.)

☐ Have your instructor check your work

9. Reinstall all components
10. Clean up area and return tools and equipment to proper storage

ACCESSORIES
UNIT XI

JOB SHEET #2 — INSPECT, CLEAN, AND TEST A HEATER

A. Tools and materials

1. Thermostatically controlled electric heater
2. Hand tool set
3. Service manual, if available
4. Solvent
5. Lint free shop towels
6. Safety glasses
7. A container of hydraulic fluid large enough to accommodate the heater
8. Thermometer
9. Fire extinguisher

B. Procedures

1. Clean — Use the solvent to remove any film buildup on the shell of the heater
2. Inspect

(NOTE: After completing each point in this inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
a. Examine the shell for any cracks		
b. Examine the electric connections to insure the terminals are not damaged or corroded		
c. Examine the heating element area for any leaks which will allow fluid to enter this area		

JOB SHEET #2

3. Test

   (NOTE: This must be done only under instructor's supervision.)

   (**CAUTION:** *Do not* touch bare wires.)

   a. Insert the heater into the container of hydraulic fluid

      (NOTE: Only the heating element portion should be immersed. Power should never be applied to the heater when not immersed.)

   b. Apply power

   c. Observe the fluid temperature

      (NOTE: It should slowly rise until the thermostat setting is reached. The heater should then turn off. This can often be heard. The temperature should get no higher than approximately 10°F greater than the thermostat setting. If the temperature continues to rise then the thermostat is not functioning properly.)

☐ Have your instructor check your work

4. Clean up area and return tools and materials to proper storage

ACCESSORIES
UNIT XI

NAME ______________________

TEST

1. Define terms associated with accessories.

   a. Accumulator — ____

   ____

   b. Heat exchanger — ____

   ____

   c. Heater — ____

   ____

   d. Thermostat — ____

   ____

2. Select functions of an accumulator by placing an "X" in the appropriate blanks.

   _____a. Provides cooling for the system

   _____b. Absorbs shock

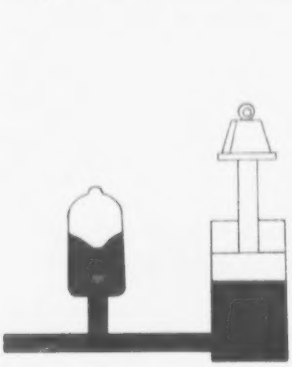
   _____c. Allows the system to build pressure gradually

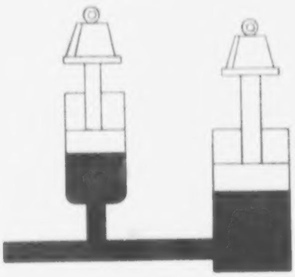
   _____d. Stores energy

   _____e. Filters dirt particles

   _____f. Maintains pressure

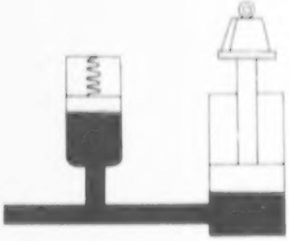
3. Identify the types of accumulators.





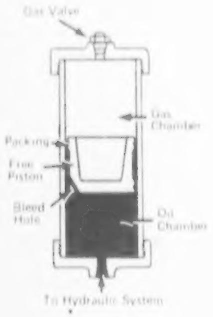
a. ______________________ b. ______________________

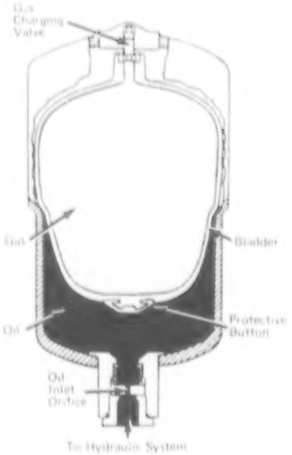
TEST



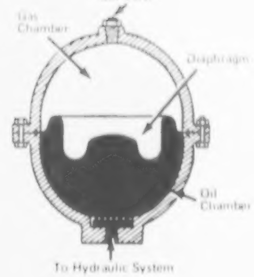
c. ______________________________

4. Identify the types of gas-loaded accumulators.


Gas Valve
Gas Chamber
Packing
Free Piston
Bleed Hole
Oil Chamber
To Hydraulic System


Gas Charging Valve
Gas
Bladder
Oil
Protective Button
Oil Inlet Orifice
To Hydraulic System

a. ______________________________ b. ______________________________


Gas Valve
Gas Chamber
Diaphragm
Oil Chamber
To Hydraulic System

c. ______________________________

TEST

5. List five safety precautions for working with accumulators.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

6. Explain reasons for using a cooler.

   ____

   ____

   ____

   ____

   ____

   ____

7. Describe types of coolers.

   a. Air-cooled cooler — ______________________________

   ____

   b. Water-cooled cooler — ______________________________

   ____

8. Match components of an air-cooled cooler with their functions.

   ______a. Holds incoming hot hydraulic fluid

   ______b. A radiator-like device over which air passes to cool the hydraulic fluid

   ______c. Located between the top and bottom tanks to protect the cooler from excessive pressure build-up during cold weather starting, and dumps fluid into the main pump when a closed-center system is depleted of fluid

   ______d. Holds cooled hydraulic fluid

   1. Core
   2. Bottom tank
   3. Top tank
   4. Bypass valve

TEST

9. List three common failures of coolers.

   a. ____________________

   b. ____________________

   c. ____________________

10. Explain reasons for using a heater.

   a. ____________________

   ____

   b. ____________________

   ____

11. Describe two types of heaters.

   a. Electric — ____________________

   ____

   b. Heat exchanger — ____________________

   ____

12. List two common failures of heaters.

   a. ____________________

   b. ____________________

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

13. Demonstrate the ability to:

   a. Inspect, clean, and test an air-cooled cooler.

   b. Inspect, clean, and test a heater.

ACCESSORIES
UNIT XI

ANSWERS TO TEST

1. a. A device for storing hydraulic energy
   b. A device for removing heat from hydraulic fluids
   c. A device for adding heat to hydraulic fluids
   d. An automatic device for regulating temperature

2. b, c, d, f

3. a. Gas-loaded accumulator
   b. Weight-loaded accumulator
   c. Spring-loaded accumulator

4. a. Piston type
   b. Bladder type
   c. Diaphragm type

5. Any five of the following:
   a. *Always* discharge stored hydraulic fluid from the accumulator prior to removing it from the system
   b. Never charge an accumulator to a pressure more than that recommended by the manufacturer
   c. *Never* fill an accumulator with oxygen; an explosion could result if oil and oxygen mix
   d. Only fill the accumulator with an inert gas such as dry nitrogen, because dry nitrogen is free of water vapor and oxygen
   e. Do not use compressed air in an accumulator
   f. Before disassembling an accumulator release both gas and hydraulic pressures
   g. Use extreme care in removing the springs from spring-loaded accumulators

6. Explanation should include:
   a. To prevent power losses in various hydraulic components, such as pumps, valves, and lines
   b. To prevent excessive operating temperatures
   c. To remove heat from the hydraulic system and increase component life

7. Description should include:
   a. Uses moving air past a radiator to dissipate the heat
   b. Uses water flowing through tubes immersed in the oil to remove the heat

8. a. 3
   b. 1
   c. 4
   d. 2

ANSWERS TO TEST

9. Any three of the following:
    a. Cooling fins on air-cooled models become clogged with dirt and debris
    b. Water tubes on water-cooled models become plugged with sediment
    c. Water leaks into fluid
    d. Fluid leaks into water

10. Explanation should include:
    a. The viscosity of hydraulic fluid is sensitive to temperature; at cold temperatures the fluid is thick and large pressure losses can occur in the lines
    b. In cold environments heaters are often used to help raise the temperature to the desired operating temperature or to help maintain the desired operating temperature

11. Description should include:
    a. Electric — Uses electric heating element to add heat to the system
    b. Heat exchanger — Uses the same principle as a cooler, except instead of removing heat, hot air or liquid is used to add heat

12. a. Electrical heating element fails
    b. Heat exchanger fails

13. Performance skills evaluated to the satisfaction of the instructor

HYDRAULIC CIRCUITS, DIAGRAMS, AND SYMBOLS
UNIT XII

UNIT OBJECTIVE

After completion of this unit, the student should be able to select true statements concerning the fluid flow in an open-center circuit and a multiple actuator open-center system and identify symbols used in a hydraulic schematic and symbols for various directional control valves. The student should also be able to draw a schematic of an open-center and closed-center system and an open-center hydraulic circuit. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to hydraulic circuits, diagrams, and symbols with their correct definitions.
2. Identify the components of a basic hydraulic circuit.
3. Distinguish between types of hydraulic circuits.
4. Complete statements concerning advantages and disadvantages of open-center and closed-center systems.
5. Select true statements concerning fluid flow in an open-center circuit.
6. Select true statements concerning fluid flow in multiple actuator open-center systems.
7. Distinguish between descriptions of valves in the neutral and shifted positions in the fluid flow in a closed-center system.
8. Identify the symbols used in a hydraulic schematic.
9. Identify the symbols for various directional control valves.
10. Draw a schematic of an open-center and a closed-center system.
11. Draw an open-center hydraulic circuit. (Assignment Sheet #1)
12. Show the oil flow in a circuit. (Assignment Sheet #2)

HYDRAULIC CIRCUITS, DIAGRAMS, AND SYMBOLS
UNIT XII

SUGGESTED ACTIVITIES

A. Provide students with objective sheet.

B. Provide students with information and assignment sheets.

C. Make transparencies.

D. Discuss unit and specific objectives.

E. Discuss information and assignment sheets.

F. Give test.

CONTENTS OF THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency masters

   1. TM 1 — Components of a Basic Hydraulic Circuit
   2. TM 2 — Types of Hydraulic Circuits
   3. TM 3 — Fluid Flow in an Open-Center Circuit
   4. TM 4 — Fluid Flow in a Multiple Actuator Open-Center Series Circuit
   5. TM 5 — Fluid Flow in an Open-Center Series-Parallel Circuit
   6. TM 6 — Fluid Flow in Closed-Center Systems
   7. TM 7 — Hydraulic Schematic Symbols
   8. TM 8 — Directional Control Valve Symbols
   9. TM 9 — Schematic Representations of Hydraulic Circuits

D. Assignment sheets

   1. Assignment Sheet #1 — Draw an Open-Center Hydraulic Circuit
   2. Assignment Sheet #2 — Show the Oil Flow in a Circuit

E. Test

F. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Fundamentals of Service, Hydraulics.* Moline, IL: Deere and Company, 1967.

B. *Fluid Power 1.* Cleveland, OH 44112: Parker-Hannifin Corp., 1975.

HYDRAULIC CIRCUITS, DIAGRAMS, AND SYMBOLS
UNIT XII

INFORMATION SHEET

I. **Terms and definitions**

A. Actuator — A device which converts hydraulic energy into mechanical force and motion

Example: Hydraulic cylinders and motors

B. Schematic — A simplified symbol which indicates essential characteristics applicable to all similar components

C. Circuit — A series of component parts connected to each other by fluid lines or passages; the complete path of flow

D. Symbol — A representation of the characteristics of a hydraulic component by means of lines on a flat surface

E. Port — Inlet or outlet connection on a valve

F. Load check — A check valve which is used to support the load in the event a line breaks or the engine dies; also used to keep a load from momentarily dropping when it is initially started to raise

G. Check valve — A valve which permits flow only in one direction

H. Float position — A position on a directional control valve which allows the load to move freely or float

I. Regenerative valve — A valve which allows the oil to flow from one side of a cylinder to the other when the load is dropped

(NOTE: This allows the load to drop quicker, because the pump does not have to supply all of the fluid. This valve is also called a quick drop valve.)

II. **Components of a basic hydraulic circuit** (Transparency 1)

A. Reservoir

B. Pump

C. Control valve

(NOTE: Some circuits may not have a control valve.)

D. Actuator

1. Cylinder
2. Motor

INFORMATION SHEET

E. Lines

(NOTE: The relief valve shown on Transparency 1 is for limiting the hydraulic pressure in the system and is essential for this particular circuit, but not all circuits will have a similar valve.)

III. **Types of hydraulic circuits** (Transparency 2)

- A. Open-center
  1. Constant flow system
  2. Oil flows continuously from the pump
- B. Closed-center
  1. Constant pressure system
  2. Pump maintains a constant pressure in the system
  3. Flow from pump is varied to satisfy the requirements of the rest of the circuit

IV. **Advantages and disadvantages of open-center and closed-center systems**

- A. Advantages of open-center systems
  1. Less wear on pump parts because of continuous flow, but not continuous pressure
  2. No constant pressure on hoses, steel lines, and connectors
- B. Disadvantages of open-center systems
  1. Systems are not responsive to demands for immediate pressure
  2. Units such as brakes and steering are not as responsive as in closed-center systems
- C. Advantages of closed-center systems
  1. All components are more responsive than with open-center systems
  2. Systems can facilitate more remote valves that can be operated simultaneously

     Example: A tractor with a loader that can raise and tilt quickly at the same time; open-center systems are much slower in multi-task operations

INFORMATION SHEET

D. Disadvantages of closed-center systems

1. Excessive pump wear

2. Constant system pressure subjects components to stress

V. **Fluid flow in an open-center circuit** (Transparency 3)

(NOTE: The term "open-center" comes from the fact that in the valve's neutral (or center) position the passage is open to return flow to the reservoir.)

A. There is constant flow from the reservoir to the pump to the rest of the system

(NOTE: Fixed displacement pumps are used for open-center systems. Gear pumps are often used but fixed displacement vane or piston pumps can also be used.)

B. Fluid flows to the control valve

1. If the valve is in the neutral position, then the fluid is returned to the reservoir

2. If the valve is shifted, then the fluid is diverted to the actuator (cylinder)

(NOTE: Fluid returned from the actuator is returned through the control valve to the reservoir.)

C. If the pressure of the system exceeds the setting of the relief valve a portion of the flow from the pump will be diverted back to the reservoir

(NOTE: The amount of flow diverted will be sufficient to insure that the system pressure does not exceed the relief valve setting.)

VI. **Fluid flow in multiple actuator open-center systems** (Transparency 4)

(NOTE: Open-center systems are often used for controlling more than one actuator. A typical example is a backhoe.)

A. Series connection

1. In the neutral position the fluid passes through the valves in series

2. When one valve is shifted the fluid is diverted to the actuator

3. The return flow from the actuator is then routed to the inlet of the next valve

4. In this configuration the first valve has priority over the next valve, etc.

INFORMATION SHEET

B. Series-parallel connection (Transparency 5)

1. Similar to the series connection, except when a valve is shifted the open-center neutral is closed and the fluid is available to all of the valves in parallel

2. If two valves are shifted at the same time the actuator requiring the least pressure will receive the flow (rather than the first valve)

3. If two actuators require approximately the same pressure then both will be operated

(NOTE: An advantage of the series-parallel configuration is the ability to operate two actuators simultaneously, assuming that the pressure required is approximately equal.)

VII. **Fluid flow in a closed-center system** (Transparency 6)

A. All valves in neutral position

1. There is no flow path from the outlet of the pressure-compensated pump to the reservoir

2. The pressure builds up at the outlet until the compensator pressure is reached and the pump "destrokes" (i.e., the pump displacement is zero) and no fluid is pumped from the pump

B. One or more valves shifted

1. The pressurized fluid is directed to the actuators, which causes a drop in the pump outlet pressure

2. The drop in compensator pressure causes the pump to "stroke" and increase the displacement until adequate flow is available to satisfy demands of all actuators

(NOTE: The pump displacement (and therefore flow) will be regulated by the compensator to maintain constant pressure on the outlet of the pump. This enables multiple actuators to operate simultaneously.)

VIII. **Symbols used in a hydraulic schematic** (Transparency 7)

A. Pumps

1. Fixed displacement

2. Variable displacement

3. Pressure compensated

INFORMATION SHEET

- B. Valves
  - 1. Directional control
  - 2. Pressure relief
  - 3. Flow control
  - 4. Check
  - 5. Pilot operated check
- C. Reservoir
  - 1. Vented
  - 2. Pressurized
- D. Filter
- E. Motor
- F. Cylinder
- G. Heat exchanger
- H. Pressure gauge
- I. Temperature gauge
- J. Flowmeter
- K. Line
  - 1. Not joined
  - 2. Joining lines

IX. **Symbols for directional flow control valves** (Transparency 8)

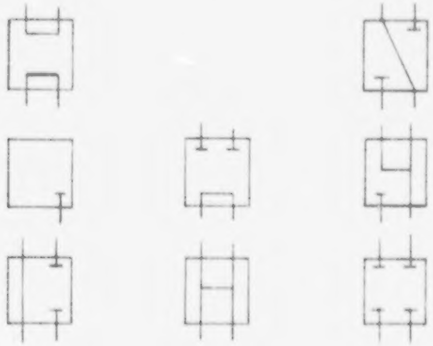
- A. Two-way, two position valve
- B. Four-way, two position valve
- C. Four-way, three position, open-center valve

INFORMATION SHEET

D. Four-way, three position, closed-center valve

(NOTE: Many variations on the center flow paths of a three position valve are common. Some are shown below in Figure 1.)

FIGURE 1



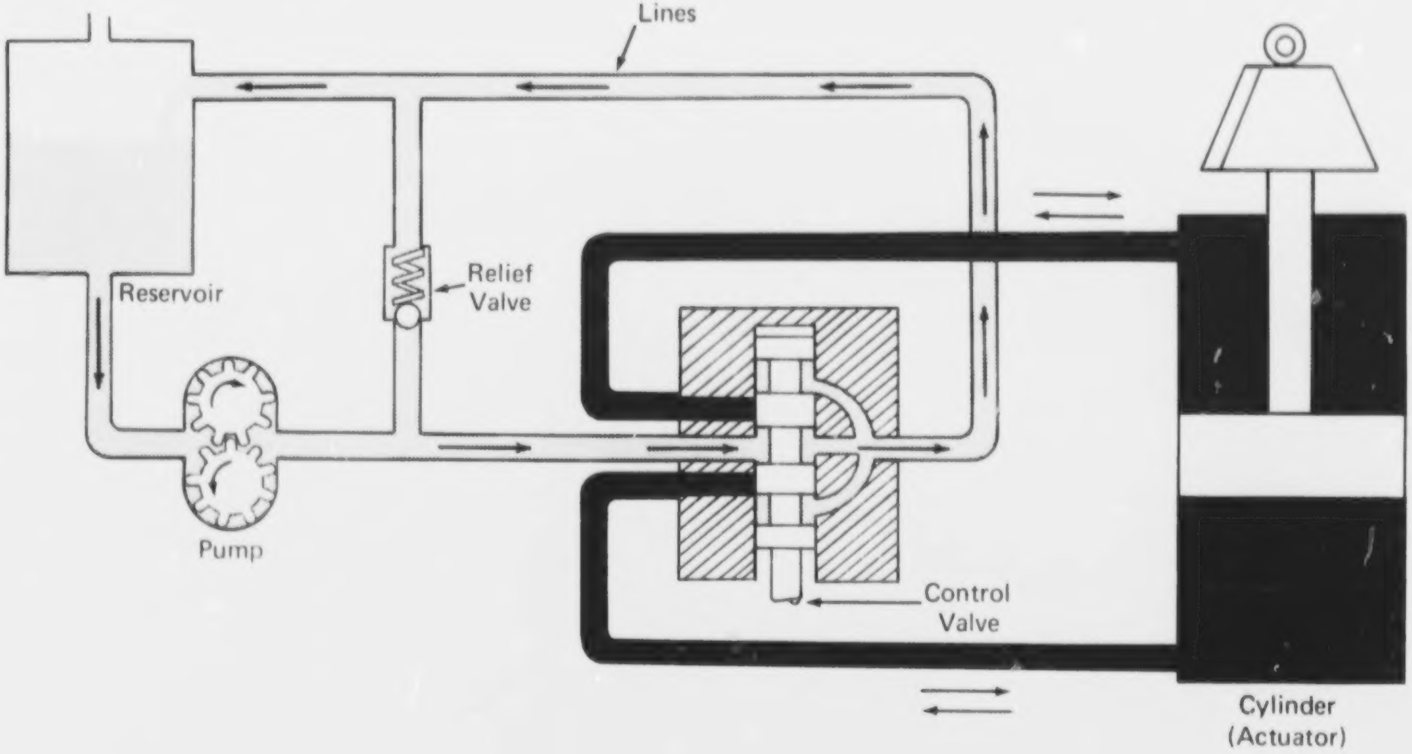
X. **Schematic representation of hydraulic circuits** (Transparency 9)

A. Open-center circuit

B. Closed-center circuit

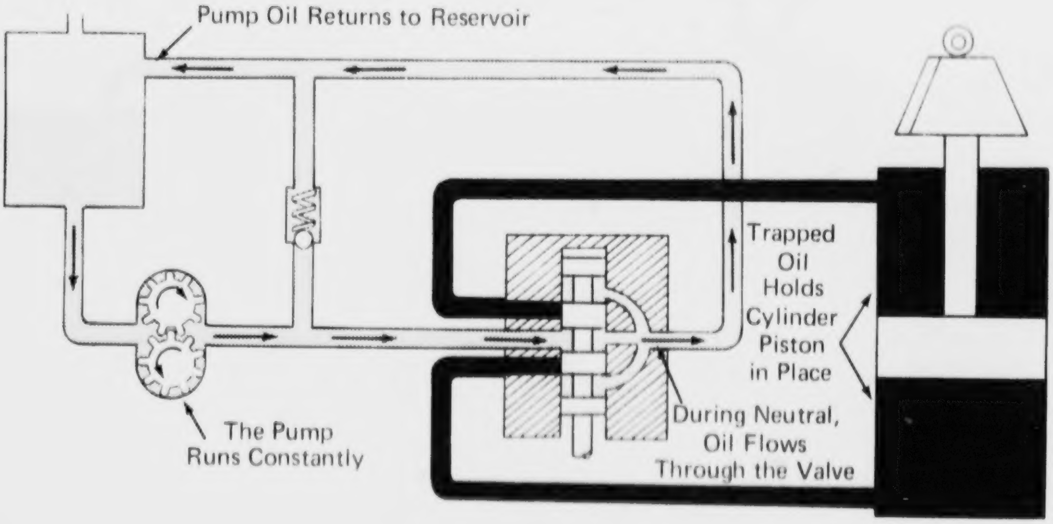
(NOTE: Transparency 9 is a schematic representation of Transparency 4.)

Components of a Basic Hydraulic Circuit

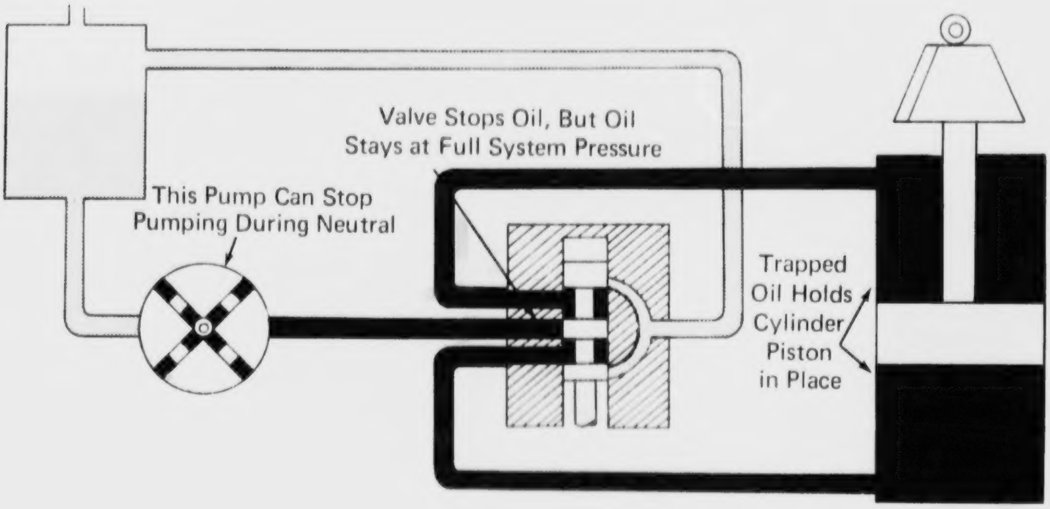

Lines
Relief Valve
Reservoir
Pump
Control Valve
Cylinder (Actuator)

Types of Hydraulic Circuits

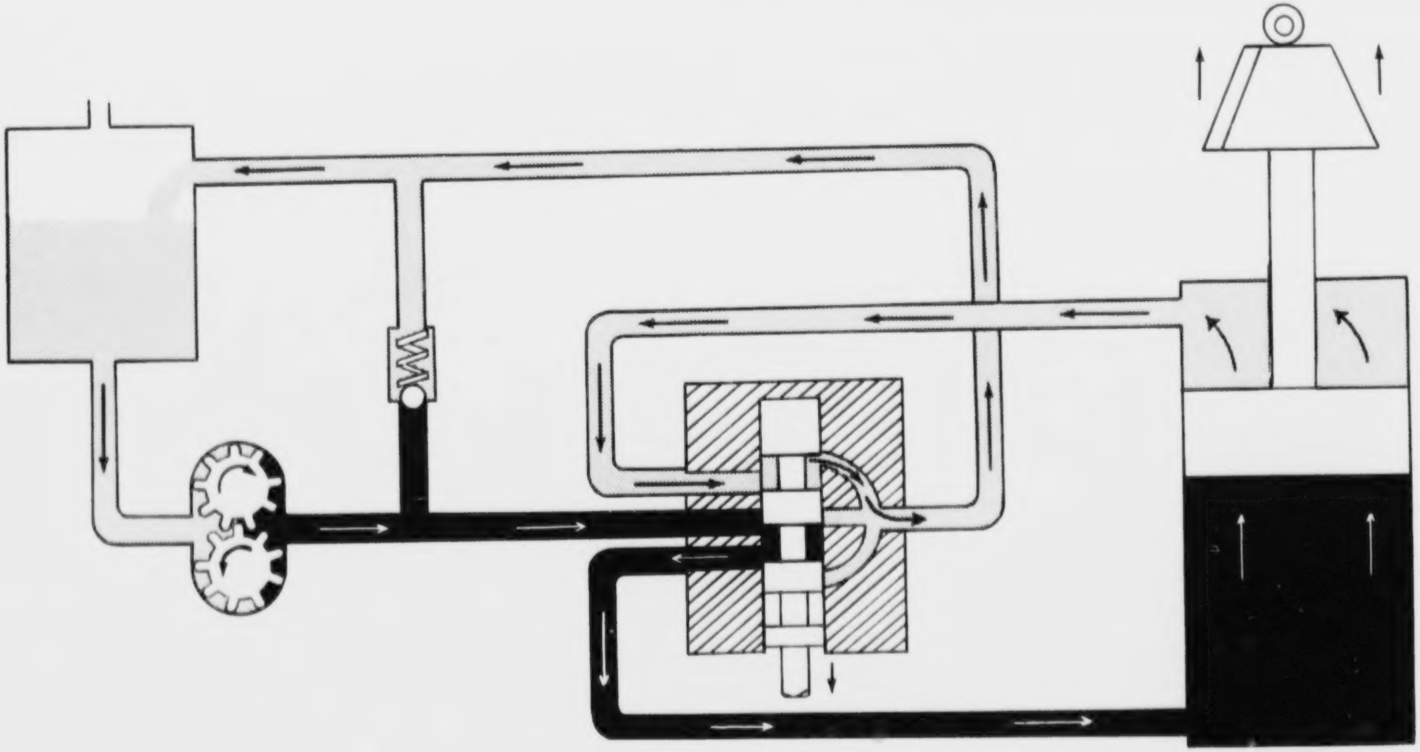
Open-Center in Neutral


Pump Oil Returns to Reservoir
Trapped Oil Holds Cylinder Piston in Place
The Pump Runs Constantly
During Neutral, Oil Flows Through the Valve

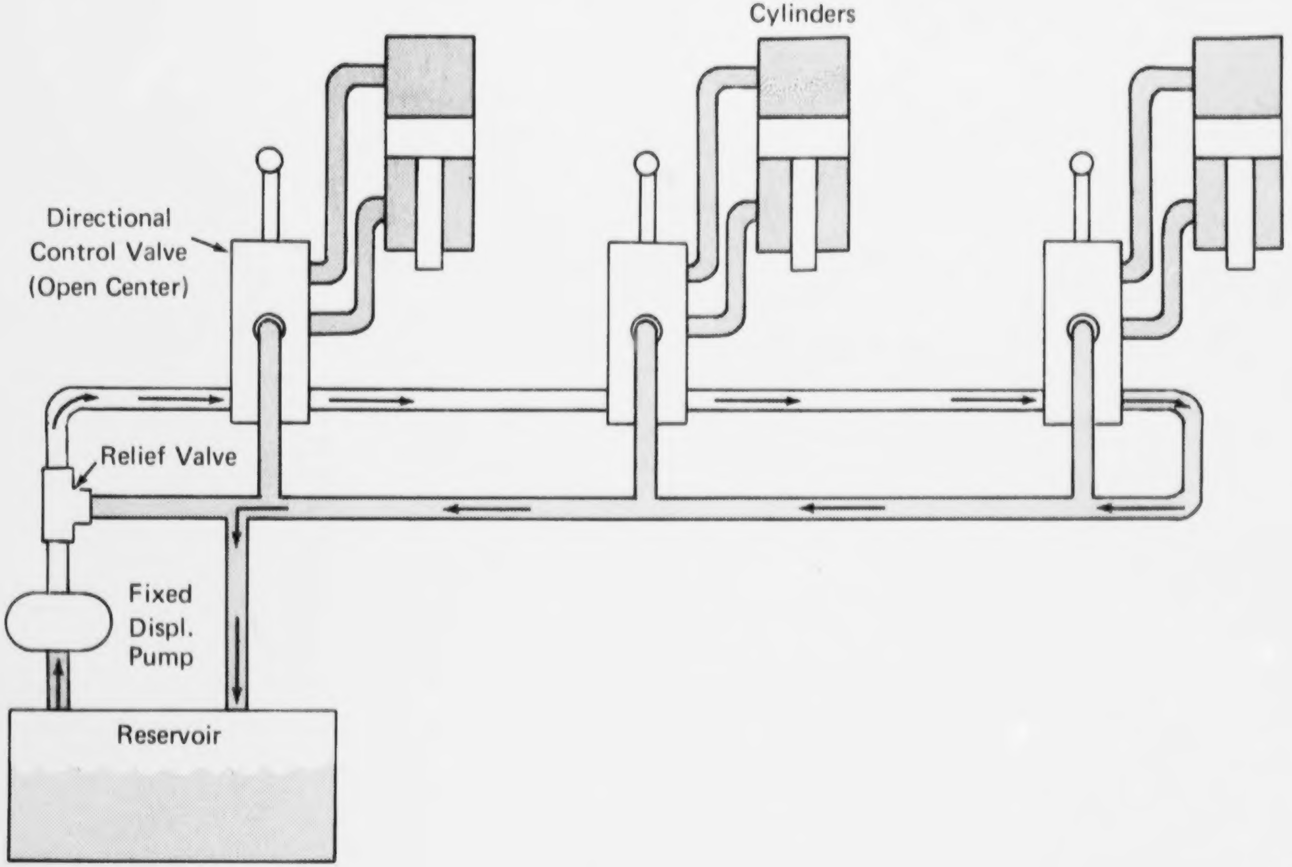
Closed-Center in Neutral


Valve Stops Oil, But Oil Stays at Full System Pressure
This Pump Can Stop Pumping During Neutral
Trapped Oil Holds Cylinder Piston in Place

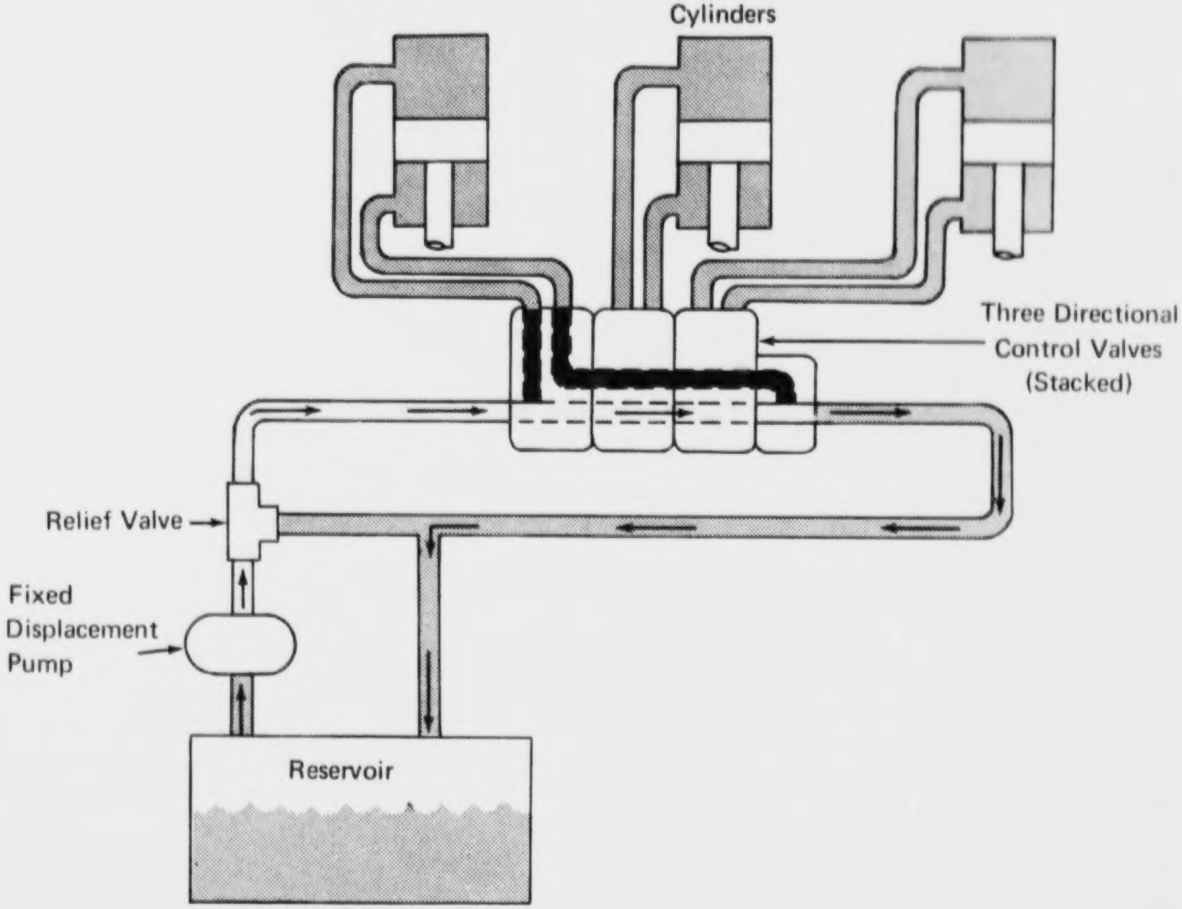
Fluid Flow in an Open-Center Circuit



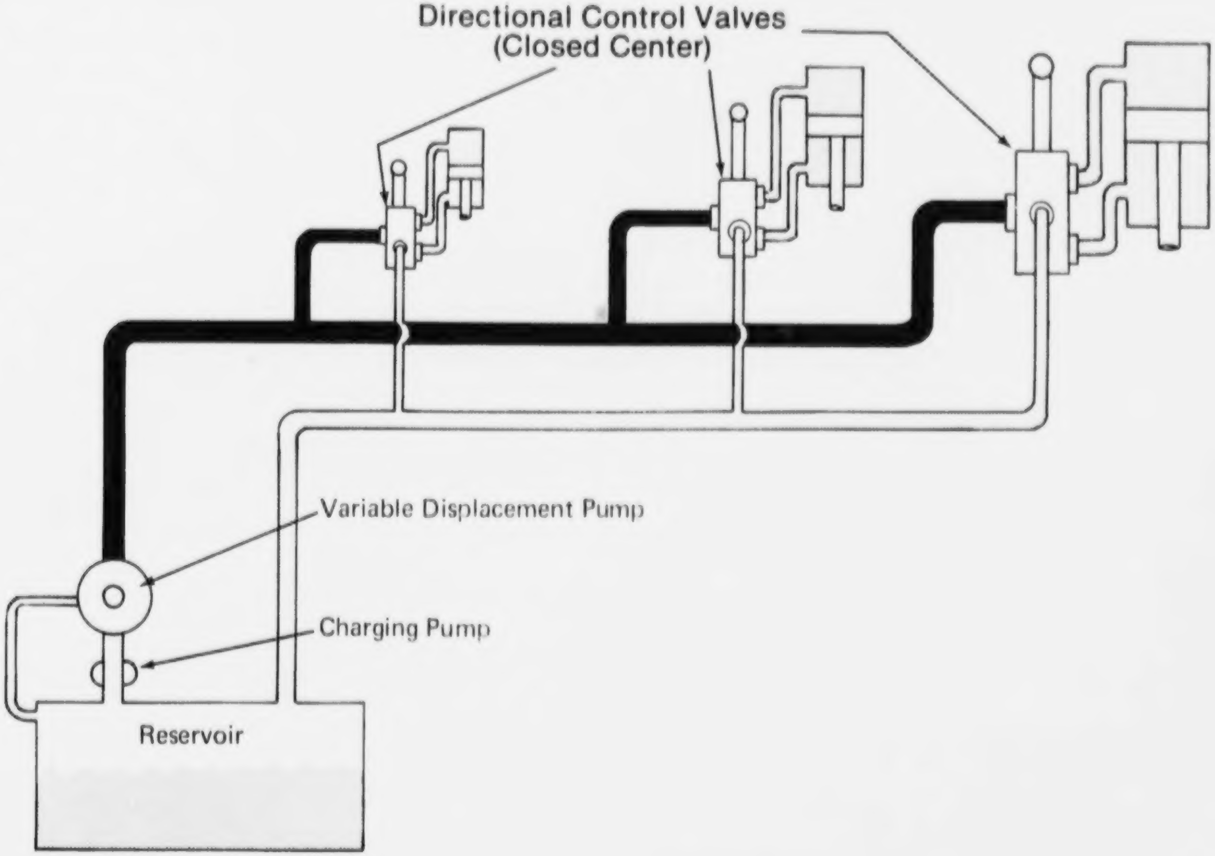
Fluid Flow in a Multiple Actuator Open-Center Series Circuit


Cylinders
Directional Control Valve (Open Center)
Relief Valve
Fixed Displ. Pump
Reservoir

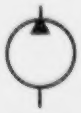
Fluid Flow in an Open-Center Series-Parallel Circuit

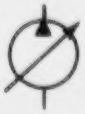

Cylinders
Three Directional Control Valves (Stacked)
Relief Valve
Fixed Displacement Pump
Reservoir

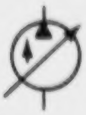
Fluid Flow in Closed-Center Systems

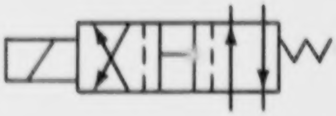

Directional Control Valves
(Closed Center)
Variable Displacement Pump
Charging Pump
Reservoir

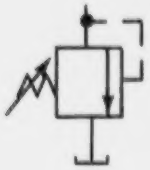
Hydraulic Schematic Symbols

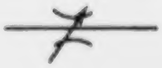

Fixed
Displacement Pump

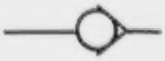

Variable
Displacement Pump

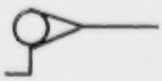

Pressure
Compensated Pump

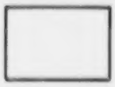

Directional Control Valve

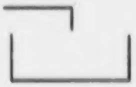

Pressure Relief Valve

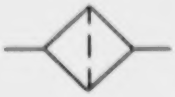

Flow Control Valve

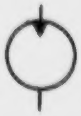

Check Valve

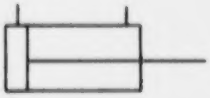

Pilot Operated Check Valve

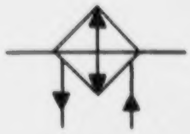

Pressurized Reservoir

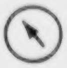

Vented Reservoir

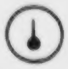

Filter

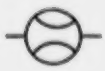

Motor

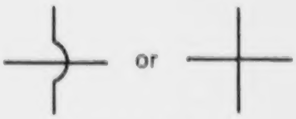

Cylinder


Heat Exchanger

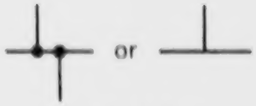

Pressure Gauge


Temperature Gauge


Flowmeter

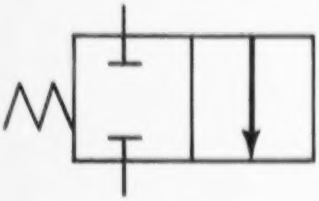


Lines not Joined

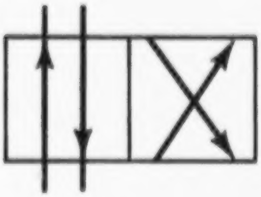


Joining Lines

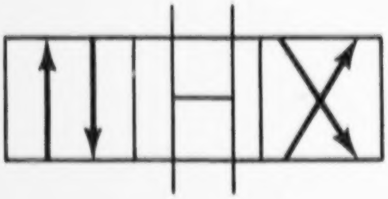
Directional Control Valve Symbols



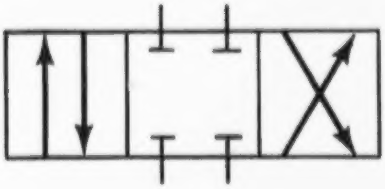
Two-way,
two position valve



Four-way,
two position valve

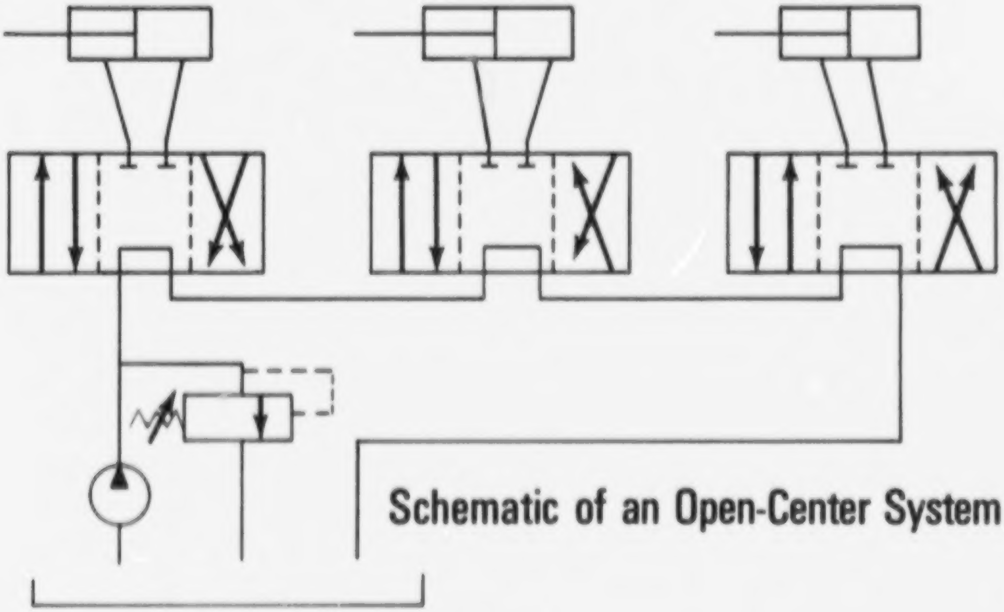


Four-way, three position
open-center

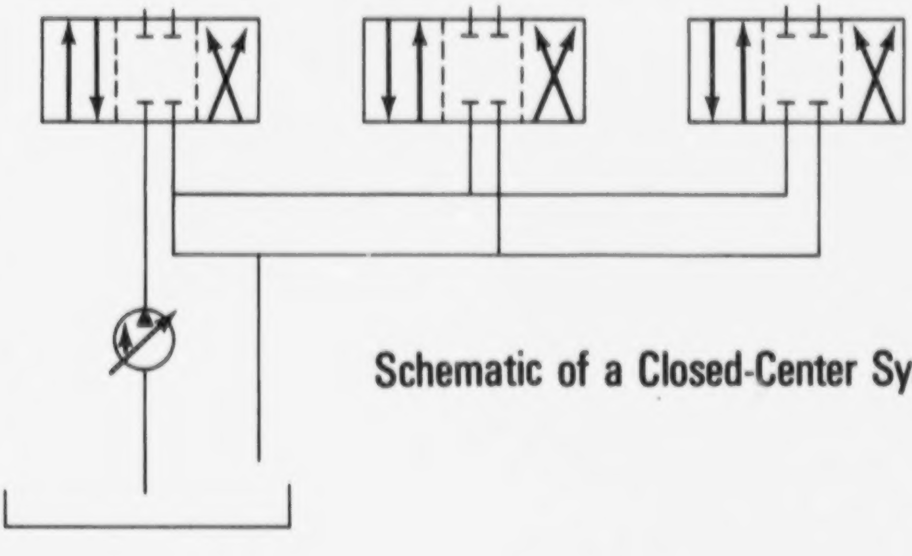


Four-way, three position
closed-center

Schematic Representations of Hydraulic Circuits



Schematic of an Open-Center System



Schematic of a Closed-Center System

HYDRAULIC CIRCUITS, DIAGRAMS, AND SYMBOLS
UNIT XII

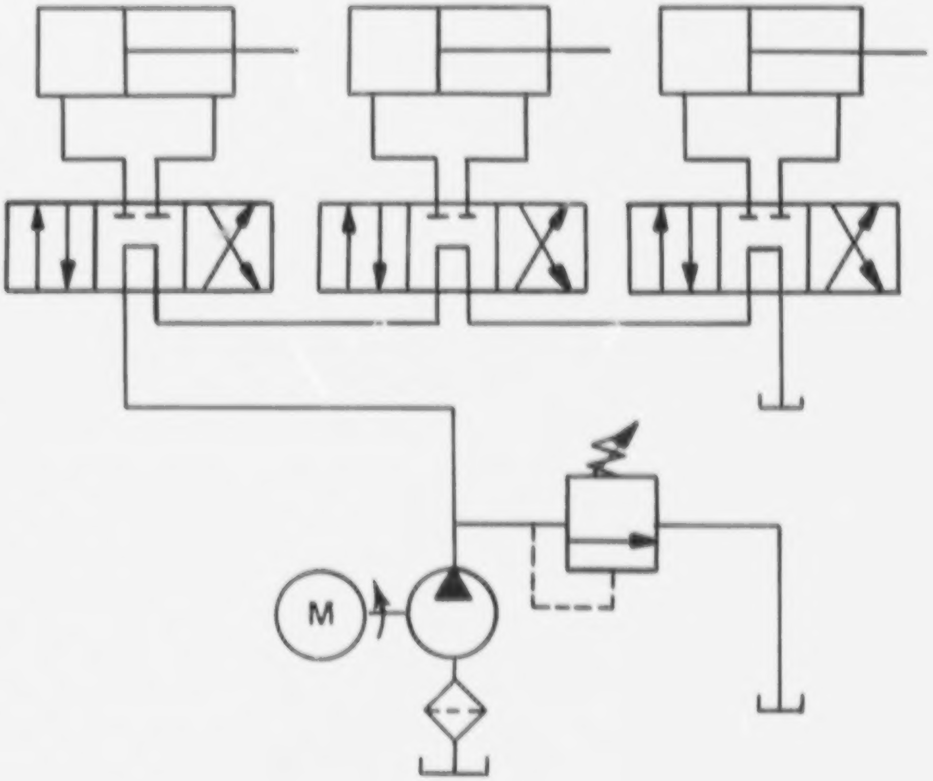
ASSIGNMENT SHEET #1 — DRAW AN OPEN-CENTER HYDRAULIC CIRCUIT

Directions: Draw an open-center hydraulic circuit which uses a reservoir, lines, pumps, relief valve, 3 position 4 way directional control valve, and cylinder.

HYDRAULIC CIRCUITS, DIAGRAMS, AND SYMBOLS
UNIT XII

ASSIGNMENT SHEET #2 — SHOW THE OIL FLOW IN A CIRCUIT

Directions: Show the oil flow in this circuit when the middle valve has been shifted to the left.



HYDRAULIC CIRCUITS, DIAGRAMS, AND SYMBOLS
UNIT XII

NAME ______________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. A series of component parts connected to each other by fluid lines or passages; the complete path of flow

_____b. A check valve which is used to support the load in the event a line breaks or the engine dies; also used to keep a load from momentarily dropping when it is initially started to raise

_____c. Inlet or outlet connection on a valve

_____d. A simplified symbol which indicates essential characteristics applicable to all similar components

_____e. A valve which permits flow only in one direction

_____f. A device which converts hydraulic energy into mechanical force and motion

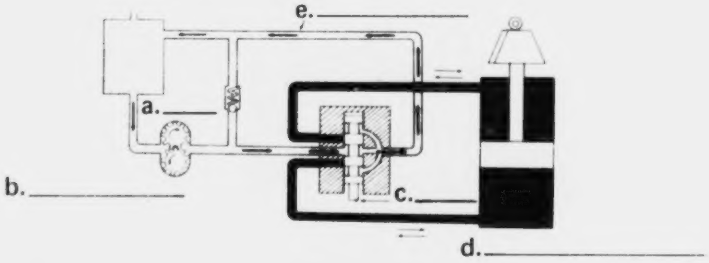
_____g. A representation of the characteristics of a hydraulic component by means of lines on a flat surface

_____h. A position on a directional control valve which allows the load to move freely or float

_____i. A valve which allows the oil to flow from one side of a cylinder to the other when the load is dropped

1. Port
2. Float position
3. Schematic
4. Actuator
5. Regenerative valve
6. Symbol
7. Circuit
8. Load check
9. Check valve

2. Identify the components of a basic hydraulic unit.



TEST

3. Distinguish between types of hydraulic circuits by placing an "O" next to open center circuit descriptions and a "C" next to closed center circuit descriptions.

______a. Constant pressure system

______b. Flow from pump is varied to satisfy the requirements of the rest of the circuit

______c. Constant flow system

______d. Pump maintains a constant pressure in the system

______e. Oil flows continuously from the pump

4. Complete the following statements concerning advantages and disadvantages of open-center and closed-center systems by inserting the word(s) that best completes each statement.

a. Advantages of open-center systems

1) Less wear on pump parts because of continuous ____________, but not continuous ____________.

2) No ____________ pressure on hoses, steel lines, and connectors

b. Disadvantages of open-center systems

1) Systems are not responsive to demands for ____________ pressure

2) Units such as ____________ and ____________ are not as responsive as in closed-center systems

c. Advantages of closed-center systems

1) All components are more ____________ than with open-center systems

2) Systems can facilitate more ____________ valves that can be operated simultaneously

d. Disadvantages of closed-center systems

1) ____________ pump wear

2) Constant system pressure subjects components to ____________

TEST

5. Select true statements concerning fluid flow in an open-center circuit by placing an "X" in the appropriate blanks.

   ______a. There is constant flow from reservoir to the pump to the rest of the system

   ______b. When fluid flows to the control valve, if the valve is in neutral position, then the fluid is returned to the reservoir

   ______c. When fluid flows to the control valve, if the valve is shifted, then the fluid is diverted to the pump

   ______d. If the pressure of the system exceeds the setting of the relief valve a portion of the flow from the pump will be diverted back to the reservoir

6. Select true statements concerning fluid flow in multiple actuator open-center systems by placing an "X" in the appropriate blanks.

   ______a. In the series connection, when one valve is shifted the fluid is diverted to the reservoir

   ______b. The series-parallel connection is similar to the series connection, except when a valve is shifted the open-center neutral is opened

   ______c. In the series connection configuration, the first valve has priority over the next valve, etc.

   ______d. In the series parallel connection, if two actuators require approximately the same pressure then both will be operated

7. Distinguish between valves in the neutral and shifted positions in the fluid flow in a closed-center system by placing an "N" next to descriptions of valves in the neutral position an "S" next to descriptions of valves in the shifted position.

   ______a. The pressure builds up at the outlet until the compensator pressure is reached and the pump "destrokes" and no fluid is pumped from the pump

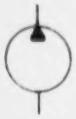
   ______b. The pressurized fluid is directed to the actuators, which causes a drop in the pump outlet pressure

   ______c. The drop in compensator pressure causes the pump to "stroke" and increase the displacement until adequate flow is available to satisfy the demands of all actuators

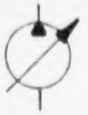
   ______d. There is no flow path from the outlet of the pressure-compensated pump to the reservoir

TEST

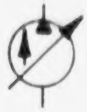
8. Identify the symbols used in a hydraulic schematic.



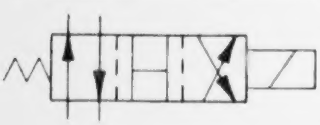
a. ______________________



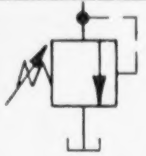
b. ______________________



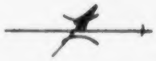
c. ______________________



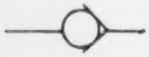
d. ______________________



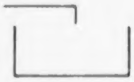
e. ______________________



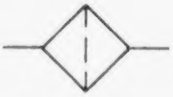
f. ______________________



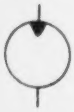
g. ______________________



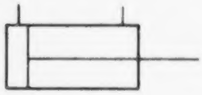
h. ______________________



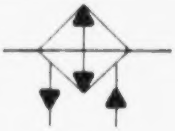
i. ______________________



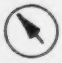
j. ______________________



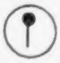
k. ______________________



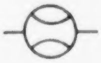
l. ______________________



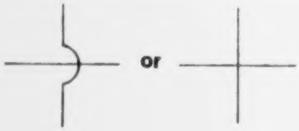
m. ______________________



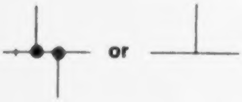
n. ______________________



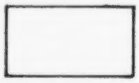
o. ______________________



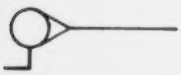
p. ______________________



q. ______________________



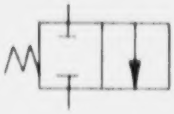
r. ______________________

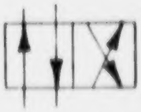


s. ______________________

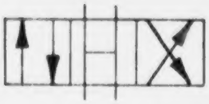
TEST

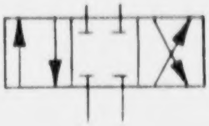
9. Identify the symbols for the various directional control valves.





a. ______________________________ b. ______________________________





c. ______________________________ d. ______________________________

10. Draw a schematic of an open-center and a closed-center system.

    a. Open-center

TEST

b. Closed-center

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

11. Draw an open-center hydraulic circuit.

12. Show the oil flow in a circuit.

HYDRAULIC CIRCUITS, DIAGRAMS, AND SYMBOLS
UNIT XII

ANSWERS TO TEST

1. a. 7
   b. 8
   c. 1
   d. 3
   e. 9
   f. 4
   g. 6
   h. 2
   i. 5

2. a. Reservoir
   b. Pump
   c. Control valve
   d. Cylinder (actuator)
   e. Lines

3. a. C
   b. C
   c. O
   d. C
   e. O

4. a. 1) Flow, pressure
      2) Constant
   b. 1) Immediate
      2) Brakes, steering
   c. 1) Responsive
      2) Remote
   d. 1) Excessive
      2) Stress

5. a, b, c

6. c, d

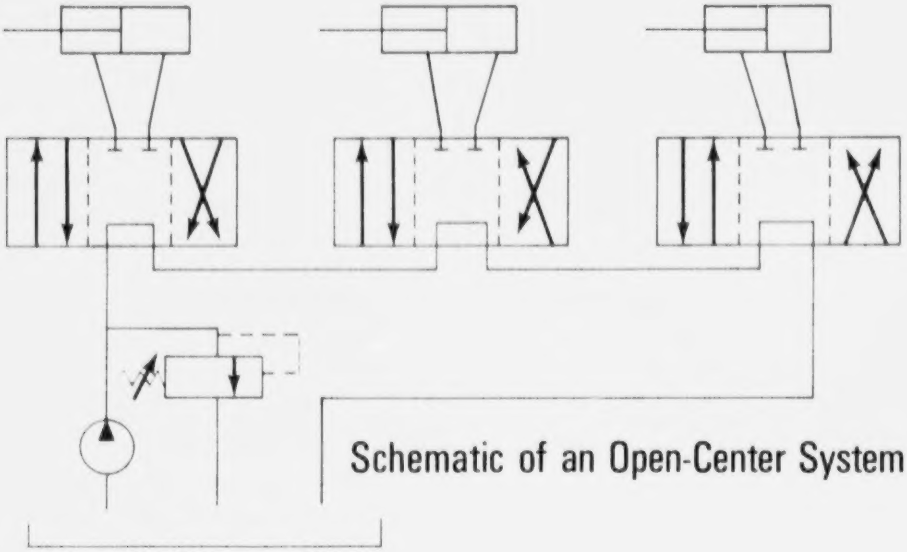
7. a. N
   b. S
   c. S
   d. N

8. a. Fixed displacement pump
   b. Variable displacement pump
   c. Pressure compensated pump
   d. Directional control valve
   e. Pressure relief valve
   f. Flow control valve
   g. Check valve
   h. Vented reservoir
   i. Filter
   j. Motor
   k. Cylinder
   l. Heat exchanger
   m. Pressure gauge
   n. Temperature gauge
   o. Flowmeter
   p. Lines, not joined
   q. Joining lines
   r. Pressurized reservoir
   s. Pilot operated check valve

ANSWERS TO TEST

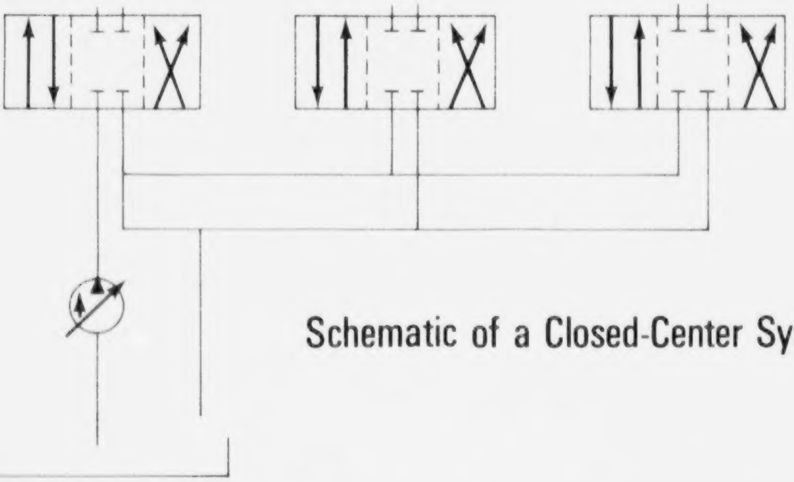
9. a. Two-way, two position valve
   b. Four-way, two position valve
   c. Four-way, three position, open-center valve
   d. Four-way, three position, closed-center valve

10. a.



Schematic of an Open-Center System

b.



Schematic of a Closed-Center System

11. Evaluated to the satisfaction of the instructor

12. Evaluated to the satisfaction of the instructor

GENERAL MAINTENANCE
UNIT XIII

UNIT OBJECTIVE

After completion of this unit, the student should be able to list steps in keeping the hydraulic system clean and steps to be performed for general maintenance on a hydraulic system. The student should also be able to perform general maintenance procedures on a hydaulic system and change hydraulic fluid and filter. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Name three reasons for performing preventive maintenance.
2. List four factors that can damage a hydraulic system.
3. Select key maintenance problems.
4. List steps in keeping the hydraulic system clean.
5. List steps to be performed for general maintenance of a hydraulic system.
6. Demonstrate the ability to:
    a. Perform general maintenance procedures on a hydraulic system. (Job Sheet #1)
    b. Change hydraulic fluid and filter. (Job Sheet #2)

GENERAL MAINTENANCE
UNIT XIII

SUGGESTED ACTIVITIES

A. Provide students with objective sheet.

B. Provide students with information and job sheets.

C. Discuss unit and specific objectives.

D. Discuss information sheet.

E. Demonstrate and discuss the procedures outlined in the job sheets.

F. Give test.

CONTENTS OF THIS UNIT

A. Objective sheet

B. Information sheet

C. Job sheets

    1. Job Sheet #1 — Perform General Maintenance Procedures on a Hydraulic System

    2. Job Sheet #2 — Change Hydraulic Fluid and Filter

D. Test

E. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Fundamentals of Service, Hydraulics.* Moline, IL: Deere and Company, 1967.

B. *Hydraulics.* Athens, GA 30602: American Association for Vocational Instructional Materials, 1974.

GENERAL MAINTENANCE
UNIT XIII

INFORMATION SHEET

I. **Reasons for performing preventive maintenance**

   A. Prolong the life of the system

   B. Reduce down-time

   C. Reduce or eliminate needless failures

II. **Factors that can damage a hydraulic system**

   A. Too much speed

   B. Too much heat

   C. Too much pressure

   D. Too much contamination

III. **Key maintenance problems**

   A. Not enough oil in the reservoir

   B. Clogged or dirty oil filters

   C. Loose inlet lines

   D. Incorrect oil in the system

IV. **Steps in keeping the hydraulic system clean**

   A. Keep the oil clean

   B. Keep the system clean

   C. Keep the work area clean

   D. When changing or adding oil, be sure to use oil recommended by the manufacturer

V. **Steps to be performed for general maintenance of a hydraulic system**

   A. Check fluid level

   B. Inspect for leaks

INFORMATION SHEET

C. Inspect hoses, lines, and drive components for excessive wear

D. Check for proper system operation

E. During operation, watch and listen to system to check for:

  1. Unusual sounds
  2. Abnormal flow through the relief valve

     (NOTE: This is often indicated by a high-pitched sound.)

  3. Cavitation

     (NOTE: This is often indicated by a low-pitched sound.)

F. Change filter and fluid according to manufacturer's recommendations

GENERAL MAINTENANCE
UNIT XIII

JOB SHEET #1 — PERFORM GENERAL MAINTENANCE PROCEDURES ON A HYDRAULIC SYSTEM

A. Tools and materials

1. Clean lint-free shop towel

2. Hydraulic fluid as specified by manufacturer

B. Procedure

1. Clean filter cap and remove

2. Visually check fluid level

   (NOTE: Level should be according to manufacturer's specifications.)

3. If the fluid level is low, add clean fluid to the reservoir

   (NOTE: The fluid must be according to manufacturer's specifications.)

4. Visually inspect the system

   (NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
a. Check for frayed hoses and protect or cover hoses that are showing signs of wear		
b. Check for damaged lines		
c. Check drive line couplings to insure they are not excessively worn		
d. Check couplings to insure they are securely attached to the shafts		

5. Replace hoses, lines, and couplings that are damaged or excessively worn and report the problem to the instructor

JOB SHEET #1

6. Check the system for leaks and tighten any fitting which is leaking

   (NOTE: If this does not stop the leak, the fitting may have to be replaced.)

7. Start the system

8. Check the operation of all the functions of the system

9. Report any improper operation or any part that fails to function properly to the instructor

10. With the system operating, listen for unusual sounds, such as cavitation or improper operation of the relief valve

11. Change the filter and fluid according to manufacturer's specification

    (NOTE: This operation will be discussed in Job Sheet #2.)

☐ Have you instructor check your work

12. Clean up area and return tools and materials to proper storage, or prepare for next job sheet as directed by your instructor

GENERAL MAINTENANCE
UNIT XIII

JOB SHEET #2 — CHANGE HYDRAULIC FLUID AND FILTER

A. Tools and materials

1. Wrench to fit reservoir drain plug
2. Wrench for removing filter
3. Clean lint-free shop towels
4. Hydraulic fluid according to manufacturer's recommendations
5. Hydraulic filter

B. Procedure

1. Operate levers to release system pressure
2. Slowly open reservoir filler cap to relieve pressure on reservoir
3. Drain the fluid by removing the drain plug in the reservoir
4. Open the inspection plate on the reservoir
5. Remove any dirt and foreign material which has settled in the bottom of the reservoir
6. Replace the inspection plate and drain plug
7. Clean the area around the filter
8. Remove the old filter
9. Clean the filter housing if it is a cartridge type filter
10. Install a new filter and tighten to manufacturer's specifications
11. Fill the reservoir with hydraulic fluid
12. Bleed system if necessary
13. Operate system and check for leaks
14. Check fluid level to insure it is still within specifications

JOB SHEET #2

15. Remove and clean the inlet screen

☐ Have your instructor check your work

16. Clean up area and return tools and materials to proper storage

GENERAL MAINTENANCE
UNIT XIII

NAME ____________________

TEST

1. Name three reasons for performing preventive maintenance.

   a. ______________________________

   b. ______________________________

   c. ______________________________

2. List four factors that can damage a hydraulic system.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

3. Select key maintenance problems by placing an "X" in the appropriate blanks.

   _____a. Too much oil in the reservoir

   _____b. Clogged or dirty oil filters

   _____c. Tight inlet lines

   _____d. Incorrect oil in the system

4. List three steps in keeping the hydraulic system clean.

   a. ______________________________

   b. ______________________________

   c. ______________________________

5. List five steps to be performed for general maintenance of a hydraulic system.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

TEST

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

6. Demonstrate the ability to:

   a. Perform general maintenance procedures on a hydraulic system.

   b. Change hydraulic fluid and filter.

GENERAL MAINTENANCE
UNIT XIII

ANSWERS TO TEST

1. a. Prolong the life of the system
   b. Reduce the down-time
   c. Reduce or eliminate needless failures

2. a. Too much speed
   b. Too much heat
   c. Too much pressure
   d. Too much contamination

3. b, d

4. Any three of the following:
   a. Keep the oil clean
   b. Keep the system clean
   c. Keep the work area clean
   d. When changing or adding oil, be sure to use oil recommended by the manufacturer

5. Any five of the following:
   a. Check fluid level
   b. Inspect for leaks
   c. Inspect hoses, lines, and drive components for excessive wear
   d. Check for proper system operation
   e. During operation, watch and listen to system to check for:
      1) Unusual sounds
      2) Abnormal flow through the relief valve
      3) Cavitation
   f. Change filter and fluid according to manufacturer's recommendations

6. Performance skills evaluated to the satisfaction of the instructor

DIAGNOSIS AND TESTING
UNIT XIV

UNIT OBJECTIVE

After completion of this unit, the student should be able to discuss steps in troubleshooting and how to use hydraulic system testers. The student should also be able to list problems and remedies for such system malfunctions as running too fast, running too slow, operating erratically, and overheating. The student should also be able to use test equipment to locate a problem in a system and test a hydraulic pump. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Define terms associated with diagnosis and testing.
2. Arrange in order the steps in troubleshooting.
3. Identify the types of hydraulic system testers.
4. Match problems with remedies for inoperative systems..
5. List remedies for problems with systems that operate erratically.
6. Match problems with remedies for systems that operate slowly.
7. Discuss two problems and remedies for systems that operate too fast.
8. Match problems with remedies for systems that overheat.
9. List problems and remedies for foaming fluid.
10. Match problems with remedies for excessive pump noise.
11. List two problems and remedies for leaking pumps.
12. Match problems with remedies for load drop when the control valve is in the neutral position.
13. List problems which can cause the control valve to stick or work hard.

OBJECTIVE SHEET

14. Select problems which can cause a control valve to leak.

15. List problems which can cause a cylinder to leak.

16. List three problems which can cause a cylinder to actually lower when a control valve is moved to slowly raise a cylinder.

17. Match problems with remedies for power steering malfunctions.

18. Match problems with remedies for brake malfunctions.

19. Demonstrate the ability to:

    a. Test a hydraulic pump. (Job Sheet #1)

    b. Locate a problem in a hydraulic system. (Job Sheet #2)

    c. Test a relief valve. (Job Sheet #3)

    d. Test a control valve. (Job Sheet #4)

    e. Test an actuator. (Job Sheet #5)

DIAGNOSIS AND TESTING
UNIT XIV

SUGGESTED ACTIVITIES

A. Provide students with objective sheet.

B. Provide students with information and job sheets.

C. Make transparency.

D. Discuss unit and specific objectives.

E. Discuss information sheet.

F. Demonstrate and discuss the procedures outlined in the job sheets.

G. Give test.

CONTENTS OF THIS UNIT

A. Objective sheet

B. Information sheet

C. Transparency Master 1 — Hydraulic System Testers

D. Job sheets

  1. Job Sheet #1 — Test a Hydraulic Pump
  2. Job Sheet #2 — Locate a Problem in a Hydraulic System
  3. Job Sheet #3 — Test a Relief Valve
  4. Job Sheet #4 — Test a Control Valve
  5. Job Sheet #5 — Test an Actuator

E. Test

F. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Fundamentals of Service, Hydraulics.* Moline, IL: Deere and Company, 1967.

B. *Hydraulics.* Athens, GA 30602: American Association for Vocational Instructional Materials, 1974.

DIAGNOSIS AND TESTING
UNIT XIV

INFORMATION SHEET

I. **Terms and definitions**

   A. Troubleshooting — The systematic diagnosis of hydraulic system malfunctions

   B. Diagnosis — A statement or conclusion concerning the nature or cause of a problem

   C. Hydraulic system tester — A device which is capable of measuring hydraulic system pressure flow and temperature and also has a valve for imposing a load onto the system

II. **Steps in troubleshooting**

   A. Know the system

   (NOTE: Study technical manuals and how the system works to familiarize yourself with the operation of the circuit.)

   B. Discuss the problems with the operator

   (NOTE: Ask operator what warning signs preceded the trouble, what previous work has been done on the system, and if similar trouble occurred before. This is frequently the most valuable troubleshooting tool of all.)

   C. Operate the machine

   D. Inspect the machine

   (NOTE: Make a close inspection for unusual noises and smells. Look for damaged lines and evidence of excessive temperature.)

   E. List the possible causes

   F. Reach a conclusion

   G. Test your conclusion

III. **Types of hydraulic system testers** (Transparency 1)

   A. By-pass tester

   B. In-line tester

INFORMATION SHEET

IV. Problems and remedies for inoperative systems

- A. No oil in system
  - 1. Fill to full mark
  - 2. Check system for leaks
- B. Oil low in reservoir
  - 1. Check level and fill to full mark
  - 2. Check system for leaks
- C. Oil of wrong viscosity — Refer to specifications for proper viscosity
- D. Filter dirty or plugged
  - 1. Drain oil
  - 2. Clean suction screen
  - 3. Try to find source of contamination
  - 4. Replace filter
- E. Restriction in system
  - 1. Oil lines could be dirty or have inner walls that are collapsing to cut off oil supply
  - 2. Clean or replace lines
  - 3. Clean orifices
- F. Air leaks in pump suction line — Repair or replace lines
- G. Dirt in pump
  - 1. Clean and repair pump
  - 2. If necessary, drain and flush hydraulic system
  - 3. Try to find source of contamination
- H. Badly worn pump
  - 1. Repair or replace pump
  - 2. Check for problems causing pump wear such as misalignment or contaminated oil

INFORMATION SHEET

I. Badly worn components — Examine and test valves, motors, cylinders, etc. for external and internal leaks

(NOTE: If wear is abnormal, try to locate the cause.)

J. Oil leak in pressure lines

1. Tighten fittings or replace defective lines

2. Examine mating surfaces on couplers for irregularities

K. Components not properly adjusted — Refer to machine technical manual for proper adjustment of components

L. Relief valve defective

1. Test relief valves to make sure they are opening at their rated pressure

2. Examine seals for damage that could cause leaks

3. Clean relief valves and check for broken springs, etc.

M. Pump rotating in wrong direction — Reverse to prevent damage

N. Operating system under excessive load — Check specifications of unit for load limits

O. Hoses attached improperly — Attach properly and tighten securely

P. Slipping or broken pump drive

1. Replace couplers or belts if necessary

2. Align them and adjust tension

Q. Pump not operating — Check for shut-off device on pump or pump drive

V. **Problems and remedies for systems that operate erratically**

A. Air in system

1. Examine suction side of system for leaks

2. Make sure oil level is correct

(NOTE: Oil leak on the pressure side of the system could account for loss of oil.)

INFORMATION SHEET

B. Cold oil

   1. Viscosity of oil may be too high at start of warm-up period

   2. Allow oil to warm up to operating temperature before using hydraulic functions

C. Components sticking or binding

   1. Check for dirt or gummy deposits, and if dirt is caused by contamination, try to find the source

   2. Check for worn or bent parts

D. Pump damaged — Check for broken or worn parts and determine cause of pump damage

E. Dirt in relief valves — Clean relief valves

F. Restriction in filter or suction line

   1. Suction line could be dirty or have inner walls that are collapsing to cut off oil supply

   2. Clean or replace suction line

   3. Check filter line for restrictions

G. Hydraulic cylinder leaking internally — Repair or replace cylinder packing

VI. **Problems and remedies for systems that operate slowly**

A. Cold oil — Allow oil to warm up before operating machine

B. Oil viscosity too heavy — Use oil recommended by the manufacturer

C. Insufficient engine speed

   1. Refer to operator's manual for recommended speed

   2. If machine has a governor, it may need adjustment

D. Low oil supply

   1. Check reservoir and add oil if necessary

   2. Check system for leaks that could cause loss of oil

E. Adjustable orifice restricted too much

   1. Back out orifice and adjust it

   2. Check machine specifications for proper setting

INFORMATION SHEET

F. Air in system — Check suction side of the system for leaks

G. Badly worn pump

  1. Repair or replace pump

  2. Check for problems causing pump wear such as misalignment or contaminated oil

H. Restriction in suction line or filter

  1. Suction line could be dirty or have inner walls that are collapsing to cut off oil supply

  2. Clean or replace suction line

  3. Examine filter for plugging

I. Relief valves not properly set or leaking

  1. Test relief valves to make sure they are opening at their rated pressure

  2. Examine valves for damaged seats that could leak

J. Badly worn components

  1. Examine and test valves, motors, cylinders, etc. for external and internal leaks

  2. If wear is abnormal, try to locate the cause

K. Valve or regulators plugged

  1. Clean dirt from components

  2. Clean orifices

  3. Check source of dirt and correct

L. Oil leak in pressure lines

  1. Tighten fittings or replace defective lines

  2. Examine mating surfaces on couplers for irregularities

M. Components not properly adjusted — Refer to machine technical manual for proper adjustment of components

INFORMATION SHEET

VII. **Problems and remedies for systems that operate too fast**

A. Adjustable orifice installed backward or not installed — Install orifice parts correctly and adjust

B. Obstruction or dirt under seat of orifice — Remove foreign material and readjust orifice

C. Pressure set too high (could cause damage) — Readjust pressure to manufacturer's specifications

VIII. **Problems and remedies for systems that overheat**

A. Operator holds control valves in power position too long, causing relief valve to open — Return control of lever to neutral position when not in use

B. Using incorrect oil

1. Use oil recommended by manufacturer

2. Be sure oil viscosity is correct

C. Low oil level

1. Fill reservoir

2. Look for leaks

D. Dirty oil

1. Drain and refill with clean oil

2. Look for source of contamination

E. Engine running too fast — Reset governor or reduce throttle

F. Incorrect relief valve pressure — Check pressure and clean or replace relief valves

G. Internal component oil leakage — Examine and test valves, cylinders, motors, etc. for external and internal leaks

(NOTE: If wear is abnormal, try to locate cause.)

H. Restriction in pump suction line — Clean or replace

I. Dented, obstructed, or undersized oil lines

1. Replace defective or undersized oil lines

2. remove obstructions

INFORMATION SHEET

- J. Oil cooler malfunctioning — Clean or repair
- K. Control valve stuck in partially or full open position — Free all spools so that they return to neutral position
- L. Heat not radiating properly — Clean dirt and mud from reservoir, oil lines, coolers, and other components
- M. Automatic unloading control inoperative (if equipped) — Repair valve

IX. Problems and remedies for foaming fluid

- A. Low fluid level — Fill reservoir and look for leaks
- B. Water in fluid — Drain and replace fluid
- C. Wrong kind of fluid being used — Use fluid recommended by manufacturer
- D. Air leak in line from reservoir to pump — Tighten or replace suction line
- E. Kink or dent in fluid lines (restricts fluid flow) — Replace fluid lines
- F. Worn seal around pump shaft — Clean sealing area, replace seal, and check fluid for contamination or pump for misalignment

X. Problems and remedies for excessive pump noise

- A. Low fluid level
  - 1. Fill reservoir
  - 2. Check system for leaks
- B. Fluid viscosity too high — Change fluid to correct viscosity
- C. Pump speed too fast — Operate pump at recommended speed
- D. Suction line plugged or pinched — Clean or replace line between reservoir and pump
- E. Sludge and dirt in pump
  - 1. Disassemble and inspect pump and lines
  - 2. Clean hydraulic system
  - 3. Determine cause of dirt

INFORMATION SHEET

F. Reservoir air vent plugged — Remove breather cap, flush, and clean air vent

G. Air in fluid

   1. Tighten or replace suction line
   2. Check system for leaks
   3. Replace pump shaft seal

H. Worn or scored pump bearings or shafts

   1. Replace worn parts or complete pump if parts are badly worn or scored
   2. Determine cause of scoring

I. Inlet screen plugged — Clean screen to prevent cavitation in the pump

J. Broken or damaged pump parts

   1. Repair pump
   2. Look for cause of damage like contamination or too much pressure

K. Sticking or binding parts

   1. Repair binding parts
   2. Clean parts and change fluid if necessary

XI. Problems and remedies for leaking pumps

A. Damaged seal around drive shaft — Tighten packing or replace seal

(NOTE: Trouble may be caused by contaminated oil. Check oil for abrasives and clean entire hydraulic system. Try to locate source of contamination. Check the pump drive shaft. Misalignment could cause the seal to wear. If shaft is not aligned, check the pump for other damage.)

B. Loose or broken pump parts — Tighten or replace parts

(NOTE: Make sure all bolts and fittings are tight. Check gaskets. Examine pump castings for cracks. If pump is cracked, look for a cause like too much pressure or hoses that are attached incorrectly.)

INFORMATION SHEET

XII. **Problems and remedies for load drop when the control valve is in the neutral position**

- A. Leaking or broken oil lines from control valve to cylinder
  1. Check for leaks
  2. Tighten or replace lines
  3. Examine mating surfaces on couplers or irregularities
- B. Oil leaking past cylinder packings or O-rings
  1. Replace worn parts
  2. If wear is caused by contamination, clean hydraulic system and determine the source
- C. Oil leaking past control valve or relief valves
  1. Clean or replace valves
  2. Wear may be caused by contamination
  3. Clean system and determine source of contamination
- D. Control lever not centering when released
  1. Check linkage for binding
  2. Make sure valve is properly adjusted and has no broken or binding parts such as spools or detent springs

XIII. **Problems which can cause the control valve to stick or work hard**

- A. Misalignment or seizing of control linkage
- B. Tie bolts too tight (on valve stacks)
- C. Valve broken or scored internally

XIV. **Problems which can cause a control valve to leak**

- A. Tie bolts too loose (on valve stacks)
- B. Worn or damaged O-rings
- C. Broken valve parts
- D. Excessive wear between a select-fit spool and valve

INFORMATION SHEET

XV. **Problems which can cause a cylinder to leak**

A. Damaged cylinder barrel

B. Rod seal leaking

(NOTE: If contamination has caused seal to wear, look for source. Wear may be caused by external as well as internal contaminants. Check piston rod for scratches or misalignment.)

C. Loose parts

D. Piston rod damaged

XVI. **Problems which can cause a cylinder to actually lower when control valve is moved to slowly raise a cylinder**

A. Damaged check valve in lift circuit

B. Leaking cylinder packing

C. Leaking lines or fittings to cylinder

D. Detent springs need adjustment

XVII. **Problems and remedies for power steering malfunctions**

A. Air in system

1. Bleed system

2. Check for air leaks

B. Internal leakage in system

1. Components may not be adjusted properly

2. Parts may be worn or broken

3. Check for cause of wear

C. System not properly timed — Time according to manufacturer's instructions

D. Worn or damaged bearings — Check and replace bearings in steering components

INFORMATION SHEET

E. Insufficient pressure

1. Check pump and relief valves

2. Contamination could cause valves to leak or pump to wear

3. Restricted filters

XVIII. Problems and remedies for brake malfunctions

A. Heavy oil or improper brake fluid

1. Warm up fluid or change to one of lighter viscosity

2. Use proper oil or brake fluid (see machine operator's manual)

(**CAUTION:** Many brake circuits use brake fluid instead of hydraulic oil. DO NOT MIX.)

B. Air in system

1. Bleed brake system

2. Find out where air is coming from

C. Contaminated oil — Clean and repair system and check for cause of contamination

D. Brake pedal return restricted

1. Clean dirt from moving parts

2. Check linkage for damage

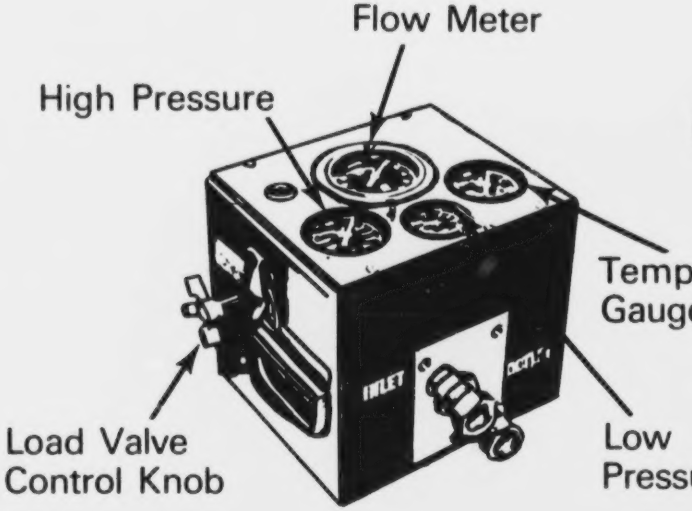
3. Brake pistons may be leaking

E. Accumulator not working (if equipped)

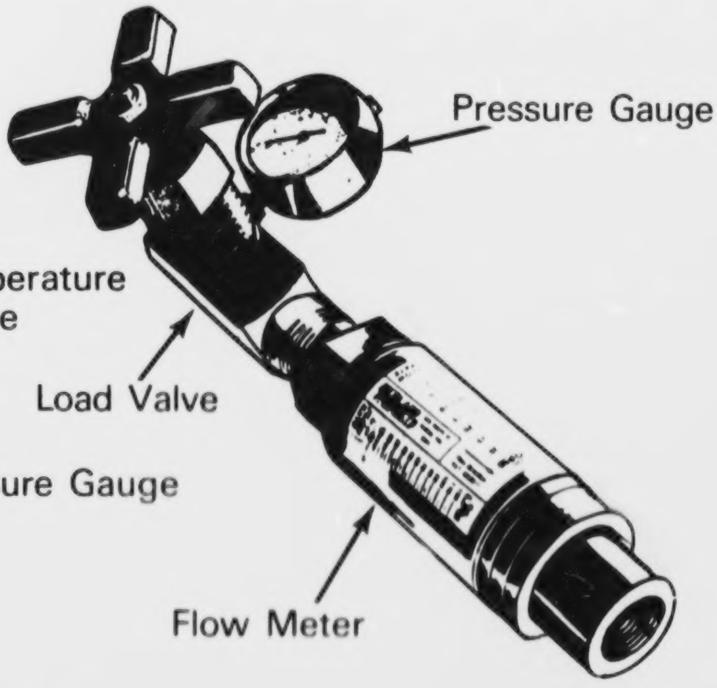
1. Check accumulator precharge

2. If accumulator is defective, repair or replace it

Hydraulic System Testers


Flow Meter
High Pressure
Temperature Gauge
Load Valve Control Knob
Low Pressure Gauge
INLET
OUTLET

By-Pass Tester


Pressure Gauge
Load Valve
Flow Meter

In-Line Tester

DIAGNOSIS AND TESTING
UNIT XIV

JOB SHEET #1 — TEST A HYDRAULIC PUMP

A. Tools and materials

1. Open-center hydraulic system
2. Hydraulic system tester
3. Hand tools
4. Service manual for hydraulic system
5. Safety glasses

B. Procedure

(NOTE: The performance of a fixed displacement pump is to be tested using a hydraulic system tester.)

1. Disconnect the line connected to the pump outlet
2. Connect the pump outlet to the inlet of the tester, connect the tester outlet to the reservoir, and make sure line is secure into reservoir
3. Open the load valve completely

   (**CAUTION:** Important! Failure to do this could cause serious damage or injury.)
4. Start pump and check for leaks
5. Close the load valve slowly so that the pump outlet is approximately 500 PSI, and let the system operate at this pressure until it has reached operating temperature
6. Open the load valve and record the no-load flow
7. Close the load valve slowly until the pump outlet pressure has reached 250 PSI and record the flow rate at this pressure
8. Close the load valve slowly and record the flow rate out of the pump in 250 PSI increments until maximu system pressure is reached, then record reading in Table 1
9. Note that the pump is faulty if it fails to supply 70% of the no-load flow at full load; the pump is also faulty if it fails to supply adequate no-load flow

   (NOTE: Refer to service manual for proper no-load flow.)

10. Stop engine, remove tester, and reconnect the pump outlet line

Outlet Pressure (PSI)	Outlet Flow Rate (GPM)
250	
500	
750	
1000	
1250	
1500	
1750	
2000*	
2250*	
2500*	
2750*	
3000*	

(**CAUTION:** *Do not* exceed rated pressure for system.)

$$\text{Flow ratio} = \frac{\text{Full load flow rate}}{\text{No-load flow rate}} = \underline{\hspace{4cm}}$$

Table 1 Pump Test Data

☐ Have your instructor check your work

11. Clean up area and return tools and materials to proper storage, or prepare for next job sheet as directed by your instructor.

DIAGNOSIS AND TESTING
UNIT XIV

JOB SHEET #2 — LOCATE A PROBLEM IN A HYDRAULIC SYSTEM

A. Tools and materials

1. Hydraulic system with a known defect
2. Service manual
3. Hand tools
4. Safety glasses

B. Procedures

(NOTE: The seven basic steps for diagnosing a system are to be followed.)

1. Review the service manual so that you will know the system
2. Discuss the symptoms with the operator or the person reporting the problem
3. Check fluid levels
4. Operate the machine

   (NOTE: Make sure no one is in the way.)

   a. Operate it until it has warmed up and observe the problem yourself
   b. Note any unusual sounds or smells
   c. Note sluggish or erratic behavior

5. Inspect the machine

   (NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
a. Look for leaks and damaged lines		
b. Check the reservoir for low or oil foaming		
c. Does it look milky? Does the oil smell scorched?		

6. List possible causes
7. Reach a conclusion — Decide on the most likely cause of the problem based on the symptoms previously observed

JOB SHEET #2

8. Test your solution

   (NOTE: Do this by reporting your findings to your instructor.)

☐ Have your instructor check your work

9. Clean up area and return tools and materials to proper storages, or prepare for next job sheet as directed by your instructor

DIAGNOSIS AND TESTING
UNIT XIV

JOB SHEET #3 — TEST A RELIEF VALVE

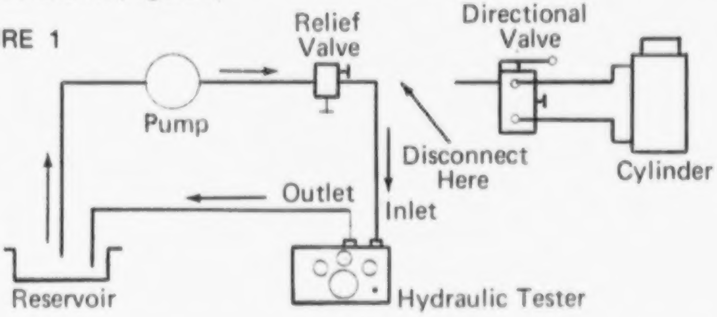
A. Tools and materials

1. Open-center hydraulic system
2. Hydraulic system tester
3. Hand tools
4. Service manual for hydraulic system
5. Operator's manual for tester
6. Safety glasses
7. Lint-free rope

B. Procedure

1. Verify that pump is functioning properly
2. If using a bypass tester disconnect the pump outlet past the relief valve and connect as shown (Figure 1)

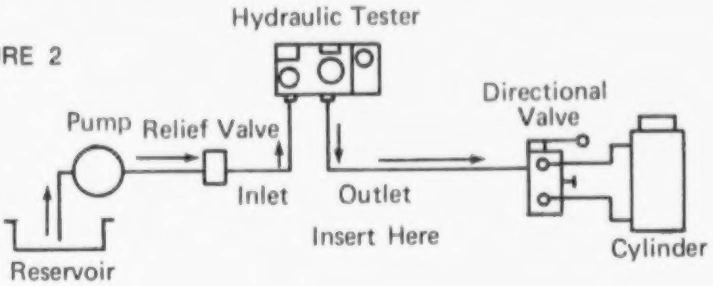
FIGURE 1


Relief Valve
Directional Valve
Pump
Disconnect Here
Cylinder
Outlet
Inlet
Reservoir
Hydraulic Tester

3. Connect the outlet of the test back to the reservoir and secure this line with line-free rope

(NOTE: If using an in-line tester connect in series after the relief valve. See Figure 2.)

FIGURE 2


Hydraulic Tester
Directional Valve
Pump
Relief Valve
Inlet
Outlet
Insert Here
Cylinder
Reservoir

JOB SHEET #3

4. Make sure the load valve is in the no-load position
5. Start hydraulic system drive and operate at rated speed
6. Operate system until fluid reaches rated temperature
7. Close the load valve slowly until the flow measured on the tester reached 0 or the pressure exceeds the maximum allowable amount
    a. If the flow is zero and the pressure is within 50 PSI of the rated setting then the relief is set to the correct value
    b. Record relief pressure: ____________ PGI
    c. If the flow is zero and the pressure is less than 50 PSI below the rated setting then slowly adjust the relief valve to the specified value
    d. Record actual setting: ____________ PSI
    e. Adjust the relief valve setting until the flow through the tester has been reduced
    f. Slowly continue to close the load until the pressure reaches the maximum value
    g. Repeat this process until the flow rate is zero and the pressure is within specification
    h. Record actual setting ____________ PSI
8. Open the load valve slowly until the pressure is 200 PSI for compound (or 500 for a simple) relief valve
9. Measure the flow rate

    (NOTE: This should be the rated flow rate of the system. If this flow rate is low then the relief valve is leaking or is faulty.)
10. Record flow rate: ____________ GPM
11. Open load valve
12. Shut drive off
13. Remove tester and reconnect lines

☐ Have your instructor check you work

14. Clean up area and return tools and materials to proper storage, or prepare for next job sheet as directed by your instructor

DIAGNOSIS AND TESTING
UNIT XIV

JOB SHEET #4 — TEST A CONTROL VALVE

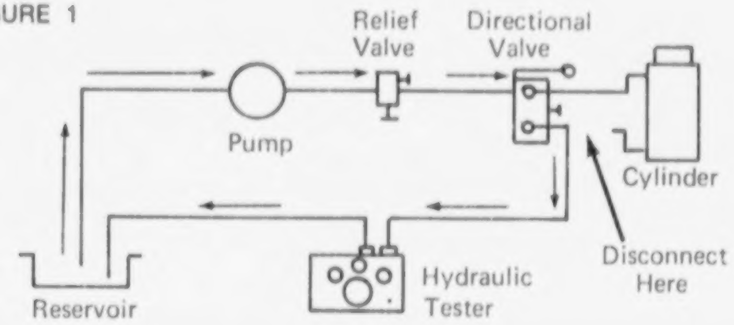
A. Tools and materials

1. Open-center hydraulic system
2. Bypass or inline hydraulic system tester
3. Hand tools
4. Service manual for tester
5. Operator's manual for tester
6. Lint-free rope
7. Safety glasses

B. Procedure

1. Verify that the pump and relief valve are functioning properly
2. Connect the tester to one of the outlet parts of the control valves similar to Figure 1

FIGURE 1


Relief Valve
Directional Valve
Pump
Cylinder
Disconnect Here
Hydraulic Tester
Reservoir

3. Connect to return line from the tester to the reservoir and secure with the lint-free rope
4. Make sure any buckets or attachments are firmly secured
5. Open the tester load valve
6. Start the pump drive and operate at rated speed

JOB SHEET #4

7. Operate the system until the fluid reaches operating temperature

8. Check to insure that buckets and attachment are firmly supported, then shift the valve to direct flow through the tester

   (**CAUTION:** Failure to properly secure attachments can result in severe bodily injury.)

   (NOTE: Do *NOT* shift the valve the other direction.)

9. With no load on the system (load valve completely open) measure the flow rate through the tester

   (NOTE: This should be approximately the rated capacity of the pump.)

10. Record the flow rate: ____________ GPM

11. Close the load valve slowly until the pressure is 100 PSI less than the relief valve pressure

12. Measure the flow rate at the above settings

13. Record flow rate ____________ GPM

    (NOTE: If the load flow rate measured above is close to the no-load flow rate previously measured then the valve is functioning properly. If a large drop occurs (more than 50 percent) then the valve is leaking and should be repaired.)

14. Record the observed condition: ____________

15. Repeat this procedure for the other outlet part (if any)

16. Turn off drive

17. Disconnect the tester

18. Reconnect the lines

☐ Have your instructor check your work

19. Clean up area and return tools and materials to proper storage, or prepare for next job sheet as directed by your instructor

DIAGNOSIS AND TESTING
UNIT XIV

JOB SHEET #5 — TEST AN ACTUATOR

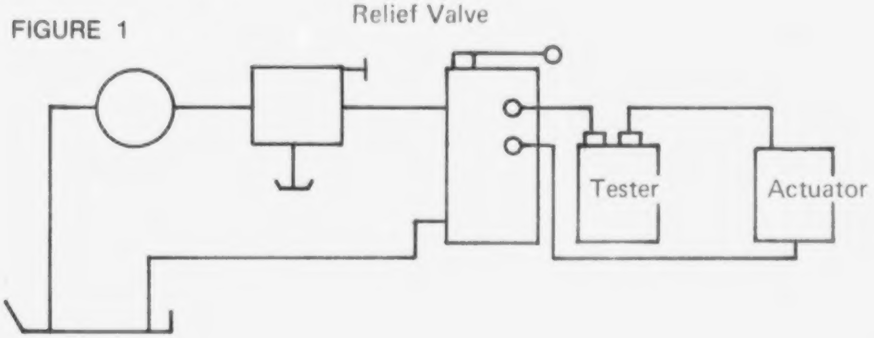
A. Tools and materials

1. Hydraulic system with an actuator (cylinder or a motor)
2. Hand tools
3. Service manual for hydraulic system
4. In-line hydraulic system tester
5. Manual for tester
6. Safety glasses
7. Device for measuring the motor shaft speed

B. Procedure

1. Verify that the pump, relief valve, and control valve are functioning properly
2. Connect the in-line tester between the control valve and actuator as shown in Figure 1

FIGURE 1



3. Open the tester load valve
4. Start the pump drive and operate at rated speed
5. Operate the system until the fluid has reached operating temperature
6. Shift the control valve to direct flow to the actuator

JOB SHEET #5

7. If a cylinder is being tested then measure the pressure and flow when the cylinder is fully retracted and extended

   Extended: Pressure ____________ PSI
   Flow ____________ GPM

   Retracted: Pressure ____________ PSI
   Flow ____________ GPM

   (NOTE: If any flow is measured then the cylinder is leaking internally and is defective and must be repaired. The pressure shows relief valve pressure in one direction and zero in the other direction. If this is not found to be correct then either the test configuration is not correct or some other component is faulty.)

8. Measure the shaft speed to the motor with no load, if a motor is being tested

9. Record the motor inlet pressure and the motor speed

   (NOTE: The speed should be close to the theoretical value.)

   No-load pressure: ____________ PSI

   No-load speed: ____________ RPM

   Theoretical flow: ____________ RPM
   if known

10. Apply a load to the motor to obtain a motor inlet pressure which is 200 PSI less than the relief valve pressure

11. Measure the pressure and speed and record

    (NOTE: The ratios of the full-load speed to the no load speed should be no less than 0.7. If it is less than this figure then the motor is defective and should be repaired.)

    Full-load pressure: ____________ PSI

    Full-load flow rate: ____________ RPM

    $\frac{\text{Full-load speed}}{\text{No-load speed}}$: ____________

12. Turn off the pump drive

13. Disconnect tester

14. Reconnect lines

☐ Have your instructor check your work

15. Clean up area and return tools and materials to proper storage

DIAGNOSIS AND TESTING
UNIT XIV

NAME ____________________

TEST

1. Define the following terms associated with diagnosis and testing.

   a. Troubleshooting — ____________________

   b. Diagnosis — ____________________

   c. Hydraulic system tester — ____________________

2. Arrange in order the steps for troubleshooting by placing the correct sequence number in the appropriate blanks.

   _____a. Operate the machine

   _____b. List the possible causes

   _____c. Reach a conclusion

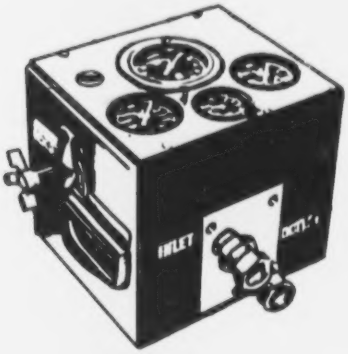
   _____d. Discuss the problems with the operator

   _____e. Test your condition

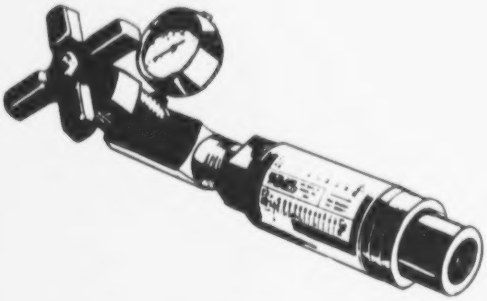
   _____f. Inspect the machine

   _____g. Know the system

3. Identify the types of hydraulic system testers.



a. ____________________



b. ____________________

TEST

4. Match the problems with remedies for inoperative systems.

_____a. 1) Fill to full mark
2) Check system for leaks

_____b. 1) Check level and fill to full mark
2) Check system for leaks

_____c. Refer to specifications for proper viscosity

_____d. 1) Drain oil
2) Clean suction screen
3) Try to find source of contamination
4) Replace filter

_____e. 1) Oil lines could be dirty or have inner walls that are collapsing to cut off oil supply
2) Clean or replace lines
3) Clean orifices

_____f. Repair or replace lines

_____g. 1) Clean and repair pump
2) If necessary, drain and flush hydraulic system
3) Try to find source of contamination

_____h. 1) Repair or replace pump
2) Check for problems causing pump wear such as misalignment or contaminated oil

_____i. Examine and test valves, motors, cylinders, etc., for external and internal leaks

_____j. 1) Tighten fittings or replace defective lines
2) Examine mating surfaces on couplers for irregularities

_____k. Refer to machine technical manual for proper adjustment or components

_____l. 1) Test relief valves to make sure they are opening at their rated pressure
2) Examine seals for damage that could cause leaks
3) Clean relief valves and check for broken springs, etc.

1. Badly worn pump
2. Components not properly adjusted
3. Pump rotating in wrong direction
4. Oil of wrong viscosity
5. Hoses attached improperly
6. Air leaks in pump suction line
7. No oil in system
8. Oil leak in pressure lines
9. Operating system under excessive load
10. Restriction in system
11. Dirt in pump
12. Slipping or broken pump drive
13. Relief valve defective
14. Oil low in reservoir
15. Badly worn components
16. Pump not operating
17. Filter dirty or plugged

TEST

______m. Reverse to prevent damage

______n. Check specifications of unit for load limits

______o. Attch properly and tighten securely

______p. 1) Replace couplers or belts if necessary
2) Align them and adjust tension

______q. Check for shut-off device on pump or pump drive

5. List one remedy for each of the following problems with systems that operate erratically.

a. Air in system — ______________________________

b. Cold oil — ______________________________

c. Components sticking or binding — ______________________________

d. Pump damaged — ______________________________

e. Dirt in relief valves — ______________________________

f. Restriction in filter or suction line — ______________________________

g. Hydraulic cylinder leaking internally — ______________________________

6. Match problems with remedies for systems that operate slowly.

______a. Allow oil to warm up before operating machine

______b. Use oil recommended by the manufacturer

______c. 1) Refer to operator's manual for recommended speed
2) If machine has a governor, it may need adjustment

______d. 1) Check reservoir and add oil if necessary
2) Check system for leaks that could cause loss of oil

______e. 1) Back out orifice and adjust it
2) Check machine specifications for proper setting

______f. Check suction side of the system for leaks

1. Low oil supply
2. Air in system
3. Oil leak in pressure lines
4. Relief valves not properly set or leaking
5. Oil viscosity too heavy
6. Valve or regulators plugged

TEST

______g. 1) Repair or replace pump
  2) Check for problems causing pump wear such as misalignment or contaminated oil

______h. 1) Suction line could be dirty or have inner walls that are collapsing to cut off oil supply
  2) Clean or replace suction line
  3) Examine filter for plugging

______i. 1) Test relief valves to make sure they are opening at their rated pressure
  2) Examine valves for damaged seats that could leak

______j. 1) Examine and test valves, motors, cylinders, etc. for external and internal leaks
  2) If wear is abnormal, try to locate the cause

______k. 1) Clean dirt from components
  2) Clean orifices
  3) Check source of dirt and correct

______l. 1) Tighten fittings or replace defective lines
  2) Examine mating surfaces on couplers for irregularities

______m. Refer to machine technical manual for proper adjustment of components

7. Adjustable orifice restricted too much
8. Badly worn pump
9. Cold oil
10. Components not properly adjusted
11. Insufficient engine speed
12. Restriction in suction line or filter
13. Badly worn components

7. Discuss two problems and remedies for systems that operate too fast.

a. ____

____

____

____

b. ____

____

____

____

TEST

8. Match problems with remedies for systems that overheat.

_____a. Return control lever to neutral position when not in use

_____b. 1) Use oil recommended by manufacturer
2) Be sure oil viscosity is correct

_____c. 1) Fill reservoir
2) Look for leaks

_____d. 1) Drain and refill with clean oil
2) Look for source of contamination

_____e. Reset governor or reduce throttle

_____f. Check pressure and clean or replace relief valves

_____g. Examine and test valves, cylinders, motors, etc. for external and internal leaks

_____h. Clean or replace

_____i. 1) Replace defective or undersized oil lines
2) Remove obstructions

_____j. Clean or repair

_____k. Free all spools so that they return to neutral position

_____l. Clean dirt and mud from reservoir, oil lines, coolers, and other components

_____m. Repair valve

1. Dirty oil
2. Oil cooler malfunctioning
3. Incorrect relief valve pressure
4. Heat not radiating properly
5. Restriction in pump suction line
6. Operator holds control valves in power position too long, causing relief valve to open
7. Dented, obstructed, or undersized oil lines
8. Low oil level
9. Automatic unloading control inoperative
10. Engine running too fast
11. Internal component oil leakage
12. Control valve stuck in partially or full open
13. Using incorrect oil

9. List four problems and remedies for foaming fluid.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

TEST

10. Match the problems with remedies for excessive pump noise.

_____a. 1) Fill reservoir
2) Check system for leaks

_____b. Change fluid to correct viscosity

_____c. Operate pump at recommended speed

_____d. Clean or replace line between reservoir and pump

_____e. 1) Disassemble and inspect pump and lines
2) Clean hydraulic system
3) Determine cause of dirt

_____f. Remove breather cap, flush, and clean air vent

_____g. 1) Tighten or replace suction line
2) Check system for leaks
3) Replace pump shaft seal

_____h. 1) Replace worn parts or complete pump if parts are badly worn or scored
2) Determine cause of scoring

_____i. Clean screen to prevent cavitation in pump

_____j. 1) Repair pump
2) Look for cause of damage like contamination or too much pressure

_____k. 1) Repair binding parts
2) Clean parts and change fluid if necessary

1. Sludge and dirt in pump
2. Worn or scored pump bearings or shafts
3. Inlet screen plugged
4. Sticking or binding parts
5. Low fluid level
6. Suction line plugged or pinched
7. Pump speed too fast
8. Reservoir air vent plugged
9. Broken or damaged pump parts
10. Fluid viscosity too high
11. Air in fluid

11. List two problems and remedies for leaking pumps.

a. ____

____

____

b. ____

____

____

TEST

12. Match problems with remedies for load drop when the control valve is in the neutral position.

_____a. 1) Check for leaks
2) Tighten or replace lines
3) Examine mating surfaces on couplers for irregularities

_____b. 1) Replace worn parts
2) If wear is caused by contamination, clean hydraulic system and determine the source

_____c. 1) Clean or replace valves
2) Wear may be caused by contamination
3) Clean system and determine source of contamination

_____d. 1) Check linkage for binding
2) Make sure valve is properly adjusted and has no broken or binding parts such as spools or detent springs

1. Oil leaking past cylinder packings or O-rings
2. Oil leaking past control valve or relief valves
3. Leaking or broken oil lines from control valve to cylinder
4. Control lever not centering when released

13. List two problems which can cause the control valve to stick or work hard.

a. ____

b. ____

14. Select problems which can cause a control valve to leak by placing an "X" in the appropriate blanks.

_____a. Tie bolts too loose

_____b. Worn or damaged O-rings

_____c. Oil level too low

_____d. Cracked reservoir

_____e. Broken valve parts

_____f. Excessive wear between a select-fit spool and valve

15. List three problems which can cause a cylinder to leak.

a. ____

b. ____

c. ____

TEST

16. List two problems which can cause a cylinder to actually lower when a control valve is moved to slowly raise a cylinder.

a. ____

b. ____

17. Match problems with remedies for power steering malfunctions.

_____a. 1) Bleed system
   2) Check for air leaks

_____b. 1) Components may not be adjusted properly
   2) Parts may be worn or broken
   3) Check for cause of wear

_____c. Time according to manufacturer's instruction

_____d. Check and replace bearings in steering components

_____e. 1) Check pump and relief valves
   2) Contamination could cause valves to leak or pump to wear
   3) Restricted filters

1. Worn or damaged bearings
2. Internal leakage in system
3. System not properly timed
4. Insufficient pressure
5. Air in system

18. Match problems with remedies for brake malfunctions.

_____a. 1) Warm up fluid or change to one of lighter viscosity
   2) Use proper oil or brake fluid

_____b. 1) Bleed brake system
   2) Find out where air is coming from

_____c. Clean and repair system and check for cause of contamination

_____d. 1) Clean dirt from moving parts
   2) Check linkage for damage
   3) Brake pistons may be leaking

_____e. 1) Check accumulator precharge
   2) If accumulator is defective, repair or replace it

1. Accumulator not working
2. Contaminated oil
3. Heavy oil or improper brake fluid
4. Brake pedal return restricted
5. Air in system

TEST

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

19. Demonstrate the ability to:

    a. Test a hydraulic pump.

    b. Locate a problem in a hydraulic system.

    c. Test a relief valve.

    d. Test a control valve.

    e. Test an actuator.

DIAGNOSIS AND TESTING
UNIT XIV

ANSWERS TO TEST

1. a. The systematic diagnosis of hydraulic system malfunctions
   b. A statement or conclusion concerning the nature or cause of a problem
   c. A device which is capable of measuring hydraulic system pressure flow and temperature and also has a valve for imposing a load onto the system

2. a. 3
   b. 5
   c. 6
   d. 2
   e. 7
   f. 4
   g. 1

3. a. By-pass tester
   b. In-line tester

4. a. 7
   b. 14
   c. 4
   d. 17
   e. 10
   f. 6
   g. 11
   h. 1
   i. 15
   j. 8
   k. 2
   l. 13
   m. 3
   n. 9
   o. 5
   p. 12
   q. 16

5. Any one of the following under each problem:
   a. 1) Examine suction side of system for leaks
      2) Make sure oil level is correct
   b. 1) Viscosity of oil may be too high at start of warm-up period
      2) Allow oil to warm up to operating temperature before using hydraulic functions
   c. 1) Check for dirt or gummy deposits, and if dirt is caused by contamination, try to find the source
      2) Check for worn or bent parts
   d. Check for broken or worn parts and determine cause of pump damage
   e. Clean relief valves
   f. 1) Suction line could be dirty or have inner walls that are collapsing to cut off oil supply
      2) Clean or replace suction line
      3) Check filter line for restrictions
   g. Repair or replace cylinder packing

6. a. 9
   b. 5
   c. 11
   d. 1
   e. 7
   f. 2
   g. 8
   h. 12
   i. 4
   j. 13
   k. 6
   l. 3
   m. 10

7. Discussion should include any two of the following:
   a. Adjustable orifice installed backward or not installed — Install orifice parts correctly and adjust
   b. Obstruction or dirt under seat or orifice — Remove foreign material and readjust orifice
   c. Pressure set too high — Readjust pressure to manufacturer's specifications

ANSWERS TO TEST

8.

a.	6	f.	3	k.	12
b.	13	g.	11	l.	4
c.	8	h.	5	m.	9
d.	1	i.	7		
e.	10	j.	2		

9. Any four of the following:
   a. Low fluid level — Fill reservoir and look for leaks
   b. Water in fluid — Drain and replace fluid
   c. Wrong kind of fluid being used — Use fluid recommended by manufacturer
   d. Air leak in line from reservoir to pump — Tighten or replace suction line
   e. Kink or dent or in fluid lines — Replace fluid lines
   f. Worn seal around pump shaft — Clean sealing area, replace seal, and check fluid for contamination or pump for misalignment

10.

a.	5	e.	1	i.	3
b.	10	f.	8	j.	9
c.	7	g.	11	k.	4
d.	6	h.	2		

11. a. Damaged seal around the drive shaft — Tighten packing or replace seal
    b. Loose or broken pump parts — Tighten or replace parts

12.

a.	3	c.	4
b.	1	d.	4

13. Any two of the following:
    a. Misalignment or seizing of control linkage
    b. Tie bolts too tight
    c. Valve broken or scored internally

14. a, b, e, f

15. Any three of the following:
    a. Damaged cylinder barrel
    b. Rod seal leaking
    c. Loose parts
    d. Piston rod damaged

16. Any three of the following:
    a. Damaged check valve in lift circuit
    b. Leaking cylinder packing
    c. Leaking lines or fittings to cylinder
    d. Detent springs need adjustment

17.

a.	5	d.	1
b.	2	e.	4
c.	3		

18.

a.	3	d.	4
b.	5	e.	4
c.	2		

19. Performance skills evaluated to the satisfaction of the instructor